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An Evaluation of Aspen Utilization in Alberta

by

© Mark S. Koepke

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled An Evaluation of Aspen Utilization in Alberta submitted by Mark S. Koepke in partial fulfilment of the requirements for the degree of Master of Science in Forest Operations.

ABSTRACT

The forest resource in Alberta contains 680 million cubic metres of deciduous merchantable timber. The timber is commonly called aspen and includes trembling aspen(*Populus tremuloides*, Michx.) and balsam poplar(*Populus balsamiferia*, L.). Although the net annual allowable cut for aspen is 11.7 million cubic metres, only 1% of this amount is utilized every year. This study evaluated optimal utilization of Alberta's untapped aspen resource.

A model using linear programming was developed to analyze utilization alternatives for aspen on the Slave Lake Forest. The model included harvesting, hauling and eight manufacturing options. Potential products were factory and construction lumber, pulp, particleboard, waferboard and plywood. The most profitable solution was an integrated complex of mills using a sawmill, a particleboard mill, a waferboard mill and a plywood mill.

The sensitivity of the model's optimal solution to change was also analyzed. The necessity for an integrated system of mills to utilize aspen was proven through variation of tree size class volumes and product prices. Aspen can also be utilized profitably when a pulp mill is substituted for the particleboard mill in the optimal solution. However, the substitution reduced the net profit by 75%. Critical operating costs and product prices were determined for various mills and products.

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"I can do all things through Christ Which strengthenth me."

Phil. 4: 13

There are many people I should probably thank for all their help in this project, but I would first like to acknowledge that God deserves the honour and glory for the things He has done in my life to allow the completion of the thesis.

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LIST OF ABBREVIATIONS

A --acre

admt --air dry metric ton(90% fibre, 10% moisture)

BDU --bone dry unit(5.664 m^3 or 200 ft^3 of oven dry chips)

cd --cord

cm --centimeter

DBH --diameter at breast height(1.4 m or 4.5 ft)

fbm --board foot

ft --foot

ft^3 --cubic feet

ha --hectare

in --inch

kg/m^3 --kilograms per cubic metre

lbs/ft^3--pounds per cubic foot

m --metre

m^3 --cubic metres

mm --millimeters

Mfbm --one thousand board feet

MMfbm --one million board feet

MMsf --one million square feet

Msf --one thousand square feet

odt --oven dry ton

1. STATEMENT OF THE PROBLEM

The aspen tree(genus *Populus*) is known by numerous names such as poplar, popple and asp. Some people think aspen is a diamond in the rough, while others call it junk or a weed. Many people burn it or curse it, but some simply love it. A few have successfully made a profit with aspen. Others have failed dismally. Researchers have evaluated this tree extensively; yet, with all this notoriety, the aspen resource in Alberta is vastly underutilized and needs development.

1.1 The Scope of the Aspen Problem

The forest resource in Alberta contains over 1.6 billion cubic metres of merchantable timber. Deciduous species make up about 40% of this figure, or 680 MMm^3 (McDonald 1979).The deciduous species include approximately 80% trembling aspen(*Populus tremuloides* Michx.), 20% balsam poplar(*Populus basamifera* L.) and a small amount of white birch(*Betula papyrifera* Marsh.)(Jackson 1974; McDonald 1979). Presently the net annual allowable cut for deciduous timber is approximately 11.7 MMm^3 as compared to 14.3 MMm^3 for conifers(Fregren 1979). The actual amount of the deciduous species harvested is estimated at only 1% of the annual allowable cut(Neilson 1975). These statistics show

that Alberta aspen[1] is an underutilized resource of wood fibre.

Aspen utilization in Alberta has been studied for many years. Extensive research has been conducted on aspen's characteristics with respect to lumber recovery, pulping potential, veneer applicability, use in composite panels and for energy production. In addition, market studies have been conducted for numerous aspen products. The Alberta Government has tried to stimulate use of aspen by setting minimal stumpage prices and by giving other economic incentives to potential operations. With the exception of a waferboard mill in Slave Lake, a planned pulp mill in Fox Creek and other minor uses, few successful ventures into aspen utilization have emerged.

1.2 The Method of Analyzing the Problem

Many analysts agree that the latent potential of aspen will not be tapped until the resource becomes economically viable (Neilsen 1975; Toovey 1979; Fregren 1979; Kennedy 1979; Wengert 1976). The problem is one of discerning which combinations of alternatives in harvesting, processing and marketing will produce a feasible and profitable solution. This kind of problem can be solved using operations research.

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[1]The term aspen will include both trembling aspen and balsam poplar,unless otherwise specified.

Operations research is the analysis, usually mathematical, of an operation or process to determine its purpose and maximum efficiency(Barnhart 1974). The analysis can either be dynamic or deterministic. Dynamic programming is a multi-staged procedure where the solution for an individual stage depends upon answers found in the preceding stage. The deterministic model evaluates a problem with known or constant parameters such as price, cost and technology. One deterministic modelling technique is linear programming. This technique evaluates a broad spectrum of variables according to stated constraints, yielding an optimum solution to the problem.

Linear programming has been used extensively in forestry. Some of the areas in which this technique has proven useful include forest management policies(Navon 1967; Jack 1967; Kidd, Thompson and Hoepner 1966; Forsten and Stewart 1970; Manning 1971; Leak 1964), harvesting and planning(Boughton 1967; Wardle 1966), minimizing wood procurement schedules(Thompson, Tilghman, Hoepner and Richards 1968), optimizing sawmill and plywood production(Szabo 1967; Ramsing 1968) and machine loading(Penick 1968; Little and Wooten 1972). Pearse and Sydneysmith(1966) and Sitter(1969) used linear programming on a broader scale. Rather than concentrating on one specific area, they applied the technique to optimize log allocation among different types of mills making various types of products. In this research, linear programming was

used in the same broad sense to evaluate the aspen utilization problem in Alberta.

1.3 The Objective of the Analysis

The objective of this analysis was to determine the optimal utilization of Alberta's aspen resource using a linear programming model. The application of linear programming to this type of problem is not new. The uniqueness of this analysis is that:

1. the focus will be specifically on the Alberta aspen situation,
2. the analysis will cover numerous activities and options from the standing tree to the market place, and
3. the model will provide a perspective on potentially profitable industry development.

The results of the analysis will describe what changes are required before aspen can compete more effectively with other wood species.

2. BACKGROUND ON ASPEN

A broad overview of the characteristics of aspen and its uses is needed in considering optimum utilization. The background will include dicussion of the resource, wood quality, harvesting techniques and products.

2.1 Characteristics of the Resource

As was mentioned in the first chapter, about 680 MMm^3 of aspen timber are available for utilization in Alberta. This aspen is located on a wide variety of sites throughout the Province, but it grows best in the boreal forest regions in central and northern Alberta(Jackson 1974). Aspen is a seral species on many sites and is eventually replaced by the coniferous forest type. In some locations, relatively stable stands of aspen can be considered *de facto* climax, because there is no forseeable replacement by conifers(Mueggler 1976).

Aspen is of a clonal habit. In one study(Barnes 1975), leaf, bud and twig characteristics were evaluated from over 1200 clones ranging from British Columbia to Colorado. Multivariate analysis revealed twenty-four population groups. Other findings show clonal variability in growth, colouration, susceptibility to disease and suckering ability(Barnes 1966; Barnes 1969; Wall 1971). Forest management of aspen is also affected by clonal characteristics. The suckering ability of the clones causes

rapid restocking of a site after a disturbance. This is a detrimental characteristic if the management objective is to change cover type. The variablility of clones plus the difficulty of growing aspen from seed makes aspen tree improvement a difficult task(Higginbotham 1981).

The aspen resource is valuable for its aesthetic characteristics, firebreak ability and watershed control (Wengert 1976). It provides food and shelter for both wild and domesticated animals. Aspen reaches maturity in 60-80 years. The species also regenerates quickly after disturbance because of its suckering ability(Schier 1976).

The high incidence of decay fungi within stands is one of the major problems in utilizing the aspen resource. Table 1 shows the percentage decay around the Lesser Slave Lake region of Alberta. Although these studies show balsam poplar stands contain only 4-7% decay, the trembling aspen figures vary from 6.2 to 42.3% decay. This variability and high percentage of decay must be taken into account when developing any method of utilization.

A number of investigators feel that a major obstacle to the utilization of aspen is inaccurate resource data(Neilson 1975; Brese and Associates 1977; Keays, Hatton, Bailey and Neilson 1974; Toovey 1979; Fregren 1979). The Alberta Forest Service(1971) has the most complete inventory statistics. The data contained in this inventory were obtained primarily from aerial photographs dating from the early 1950's to the early 1960's. Companies may be very reluctant to make large

TABLE 1

PERCENT DECAY OF ASPEN IN LESSER SLAVE LAKE REGION

Age of Trees (years)	Paul and Etheridge, 1958		Bailey and Dobie, 1977		McDonald, 1979	
	TA	BP	TA	BP	TA	BP
30	11.8	2.9	6.2	6.2	...	...
40	13.5	8.7	6.2	6.2	...	...
50	30.2	8.2	6.2	6.2	...	...
60	40.0	7.4	8.4	5.0	10–15	...
70	42.3	8.4	8.4	5.0	10–15	...
80	39.6	10.1	8.4	5.0	25–30	...
90	36.0	11.4	12.2	5.5	25–30	...
100	33.1	13.4	12.2	5.5	...	...
110	30.2	15.2	12.2	5.5	...	...

Source: Paul, G. and D.E. Etheridge. 1958. Decay of aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamiferia* L.) in the Lesser Slave Lake Region in Alberta. Joint Interim Rep., Gov. of Alta., Dep. Lands For., Can. Dept. Ag., For. Biol. Div., Calgary and Edmonton, Alta. pp. 12-13.

Source: Bailey, G.R. and J. Dobie. 1977. Alberta poplars—tree and log quality. Envirn. Can., West. For. Prod. Lab., Inf. Rep. VP-X-155, Vancouver, B.C. p. 4.

Source: McDonald, C.S. 1979. Status of the hardwood resources in Alberta. *In:* Utilization of Western Canadian Hardwoods Symp. Proc., ed. J.A. McDonald and M.N. Carroll. Forintek Can. Corp., Spec. Pub. No. SP-2, Vancouver, B.C. p. 25.

Note: TA—trembling aspen: BP—balsam poplar.

capital investments for aspen utilization with a poor and limited data base. In the next few years, the Alberta Forest Service will complete a new forest inventory which should provide new information on the aspen resource.

2.2 Characteristics of the Wood

Aspen is a fine-grained, light-weight hardwood. The wood is characterized by numerous small vessels scattered evenly throughout the fibres. Fibres make up 66% of the wood volume and are one-third to one-sixth of the length of fibres generally found in softwoods (Kennedy 1974). Annual rings are often not conspicuously defined due to the relative uniformity of the cells(Wengert 1975). The wood is white to light brown in colour. Discolouration is common in areas of bacterial wetwood[2] and incipient decay. Aspen has a slight characteristic odour when wet; it is odourless and tasteless when dry.

A major indicator of the strength of wood is its specific gravity. Aspen has low specific gravity which indicates low strength properties. Various specific gravity values for trembling aspen and balsam poplar given in the literature are found in Table 2. Wetwood in trembling aspen causes the specific gravity to be 0.03-0.04 units lower than for unaffected wood, while wetwood in balsam poplar has

[2]Wetwood and wet pockets are areas of high moisture content surrounded by wood of lower moisture content. They are caused by bacteria.

TABLE 2

SPECIFIC GRAVITY OF TREMBLING ASPEN AND BALSAM POPLAR

Species	Condition	Jessome, 1977	U.S. Forest Prod. Lab., 1974	Irwin and Dole, 1961	Erickson, 1972
trembling aspen	green	0.374	0.350	0.380	0.367
	air-dry	0.408	0.380	0.420*	0.455*
balsam poplar	green	0.372	0.310	0.370	...
	air-dry	0.415	0.340	0.420*	...

Source: Jessome, A.P. 1977. Strength and related properties of woods grown in Canada. Fisheries and Envirn. Can., East. For. Prod. Lab., For. Tech. Rep. 21, Ottawa, Ont. p. 32.

Source: U.S. Forest Products Laboratory. 1974. Wood handbook: wood as an engineering material. U.S.D.A., Ag. Handb. 72, rev., Washington, D.C. pp. 4-7, 4-8.

Source: Irwin, J.D. and J.A. Doyle. 1961. Properties and utilization of Canadian poplars. Can. Dep. Forest., For. Prod. Res. Br., Tech. Note 24. p. 22.

Source: Erickson, J.R. 1972. The moisture content and specific gravity of the bark and wood of northern pulpwood species. U.S.D.A., For. Ser. Res. Note NC-141. p. 3.

*Specific gravity using oven dry volume.

little effect(Kennedy 1974; Haygreen and Wang 1966). Kennedy(1968) reports in general, the the compression strength of trembling aspen is low when compared to species of similar specific gravity. He notes however, that bending strength of air-dried wood and the modules of elasticity in both green and air-dried specimens do not differ significantly from similar species. Wengert(1975) states that trembling aspen is also high in toughness. Volumetric shrinkage of aspen during drying ranges from 11.6-11.8%(Kennedy 1968). The large tangential to radial shrinkage ratio in trembling aspen can give rise to cupping and diamonding during the drying process. Tension wood and wet pockets further complicate uniform drying. Research by MacKay(1980) has proven that aspen can be dried efficiently and effectively despite these difficulties.

Other characteristics of aspen need to be considered. Nail-holding strength is low, but the uniform texture and short fibres allow the use of large nails without splitting the wood. Aspen does not dull tools quickly or require high power consumption when machining. Unless extra care is taken, though, the wood does not cut cleanly resulting in a fuzzy surface. The wood has excellent paint holding ability and provides a good surface for printing with ink. Aspen glues well but the wood is absorptive. Stain often appears blotchy when it is not applied carefully. Uniform preservative treatment of aspen is difficult because the tyloses in the heartwood and areas of wetwood resist

penetration of the preservative.

2.3 Characteristics of Harvesting

Harvesting is a critical area when considering the economics of aspen utilization. At least two companies ceased operations primarily due to high harvesting costs(Koepke 1976). The harvesting technique most commonly used in aspen is manual felling with wheeled skidding. Trees are hauled as full-trees, tree-lengths or 2.54 m(100 in) bolts. Harvesting costs are high for a number of reasons, one major one being the large amount of decay within the stands. As was noted earlier, some older stands may be over 40% decayed. Ideally, all decayed material should be left in the bush but detecting decay is often difficult. Many trees have substantial decay without having visual indicators such as conks or scars. Even with the presence of such external indicators, serious decay is not necessarily found(Bailey 1974). The time required to handle this decayed material significantly increases harvesting cost.

Another reason for increased harvesting costs in aspen involves the hauling of the trees to the mill or concentration yard. On the average, green aspen weighs 805 kg/m^3(50.2 lbs/ft^3), compared to spruce at 649 kg/m^3 (40.5 lbs/ft^3)(Dobie and Wright, 1975). The added weight plus a large amount of crook and sweep naturally lead to higher hauling costs. One B.C. firm reported that the volume hauled

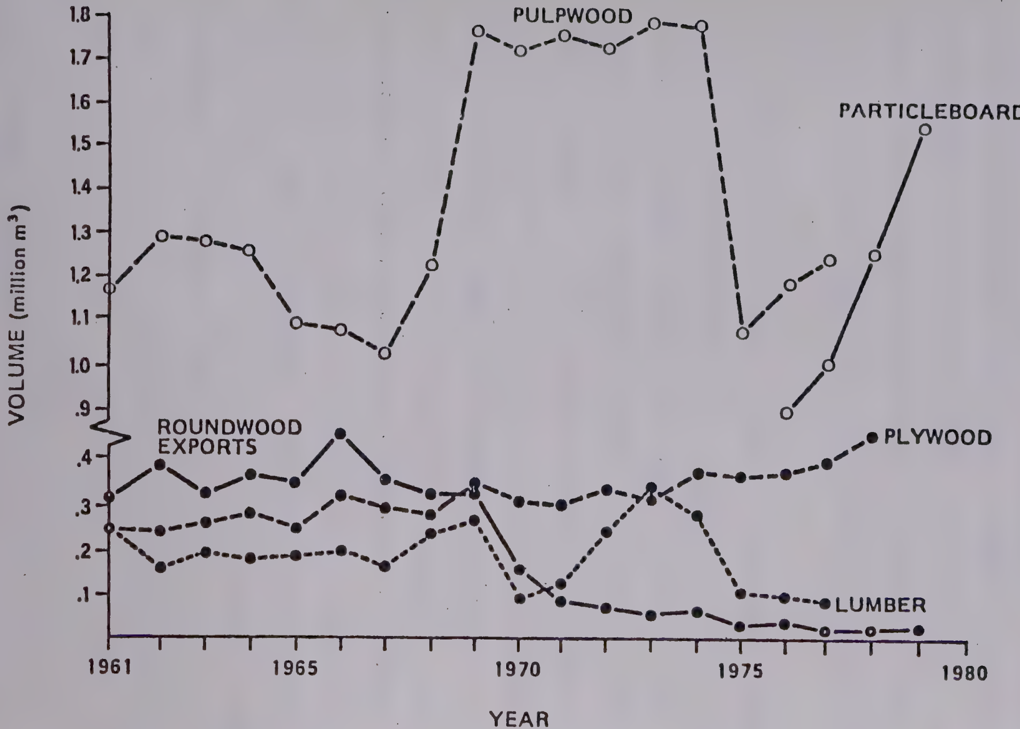
per load of aspen was 13% less than conifer loads(Neilsen 1975).

2.4 Characteristics of the Products

Aspen can be utilized to produce a wide variety of products. These products can be reviewed under the general categories of solid wood, veneer, composite panel, fibre and minor products.

2.4.1 Solid wood products

Solid wood products made from aspen include construction lumber, factory lumber and other solid wood uses. Nielsen(1980) reported that aspen lumber production has declined steadily from 130,000 m^3 in 1973 to 30,000 m^3 in 1977(Figure 1). Construction aspen lumber is listed in the "F" species group of Code of Recommended Practices for Engineering Design in Timber(Canadian Standards Association 1972). The "F" group is called the poplar group and includes trembling aspen, largetooth aspen and balsam poplar. The lumber in the poplar group has tension and bending strength equivalent to that of the spruce-pine-fir(SPF) group(Canadian Standards Association 1972). There is disagreement in the literature on whether the stiffness and compression strength of poplar is less than the limits establised for the SPF group. A number of studies report poplar to be weaker in stiffness and compression(Laminated



Source: Nielson, R.W. 1980. Poplar utilization trends and prospects. *In*: Second Annual Meeting of the Poplar Council of Can. Ont. For. Res. Centre, Maple Ridge, Ont. p. 70.

Figure 1. Canadian poplar consumption by end use

Timber Institute of Canada 1972; Kennedy 1974; Canadian Lumber Standard Administration Board 1980). However, Littleford and Roff's(1975) tests showed trembling aspen and balsam poplar to be stiffer than the limits set for the SPF group. Aspen construction lumber is presently being used for pallets, crates, reels and mine timbers(Koepke 1976; Nielsen 1980).

Aspen factory lumber is used in panels, dimension stock, shelving and furniture components(Reeves 1974). The market for these products is excellent(Harris 1968; Hovarter 1978; Dufrese, McLaggan, Dargnault Inc. 1970; Ceasar 1974). The difficulty in utilizing aspen for this market is is the lack of sufficient quantities of high grade lumber. Bailey(1973) concluded that extensive manufacturing of factory lumber is limited due to the generally small diameters of aspen available. Flann(1974) estimates only 10-30% of a given regional aspen volume would be suitable for these types of products. The remaining residue and low grade material must be utilized before factory lumber production can become economically viable(Brese *et.al.* 1977; Leach and Gillies 1972; Flann 1974; Nielson 1980; Bailey 1973).

2.4.2 Veneer products

Consumption of aspen for the making of plywood has shown a moderate but steady increase from 1973 to 1978(Figure 1). Aspen plywood shipments in 1978 totalled

113.3 Mm^3 (128 MMsf,3/8 in basis) utilizing 454 Mm^3 of peeler logs(Nielson 1980). The manufacturing process is essentially the same as for softwood plywood. Higher production costs are incurred because of decay, glue absorption, spin-out and longer drying and press times.

Aspen plywood can be used for painted and unpainted furniture, built in fixtures, wall panelling, furniture backs, sheathing, floor underlay and decking. It has also been approved for core or crossband material with softwood face veneers(Neilson, 1975). A new veneer product called laminated veneer lumber is now being evaluated for its economic feasibility(Hyslop 1980). Laminated veneer lumber(LVL) is a series of parallel ply laminations hot-press bonded together to produce a lumber-type product. Aspen LVL is made using 6 mm(1/4 in) veneers. Laminated veneer lumber appears to have excellent marketing potential for furniture parts and construction applications.

The limiting factor on expanding aspen veneer production is the resource itself. Harris(1968) noted that many aspen plywood producers either ceased operations or switched to alternate species due to the inability to secure adequate supplies of peeler bolts. This factor, plus the higher costs of harvesting and production severely limit the potential growth of aspen veneer production.

2.4.3 Composite panel products

Aspen composite panel products include insulation board, hardboard, medium-density fibreboard(MDF), particleboard and flakeboard[3]. Tables 3 and 4 show general information concerning raw materials, density and end use of these products. Medium-density fibreboard, particleboard and flakeboard consumed an estimated 1,007 Mm^3 of aspen roundwood in 1977(Nielson 1980). The particleboard line[4] in Figure 1 shows a dramatic increase in aspen consumption for these end products starting in 1976. This trend is expected to continue mainly on the strength of new flakeboard production, particularly waferboard. The expansion of waferboard manufacturing from 1979-1984 given by Gummeson(1979) can be seen in Table 5. While MDF, particleboard and flakeboard consumption is increasing, the demand for insulation board and hardboard remains relatively low. This is basically due to petro-chemical products being substituted for traditional insulation board and hardboard applications.

The limiting factors on expansion of aspen MDF, particleboard and flakeboard are transportation and binder costs. Transportation costs are high for these products because of the heavy weight of the panels and the distance from the mill to large marketing areas. Binder costs will

----

[3] Flakeboard includes both strand or chip board and waferboard.

[4] The particleboard line includes data for MDF, particleboard and flakeboard. Insulation board and hardboard consumption data are included in the pulpwood statistics.

TABLE 3

BASIC PRODUCT-BASIC END USE RELATIONSHIP OF COMPOSITE BOARDS

Basic Product	Binder Type	Density (kg/m^3)	Basic End Use	
Insulation board	none	272 - 512	non-structuctral sheathing (exterior-interior)	
			ceiling tiles	
Hardboard (S2S S1S)	P. F.	880 - 1120	3 - 6 mm	wall paneling
	none	880 - 1120	3 - 6 mm	industrial panel
		720 - 880	9 - 11 mm	exterior siding
		960 - 1120	3 mm	door skins (ext.-int.)
Medium-density fibreboard	U. F.	720 - 960	3 - 6 mm	interior wall panel door skins
		640 - 960	9 - 32 mm	industrial core board
Particleboard	U. F.	608 - 720	9 - 19 mm	construction-grade panel underlayment
Industrial flakeboard	U.F.	400 - 560	28 - 38 mm	door core
Structural flakeboard	P. F.	640 - 720	6 - 9 mm	all-purpose wall cladding (ext.-int.)
		608 - 720	9 - 19 mm	structural sheathing and decking

Source: Vajda, P. 1979. Particleboard and fiberboard processes. *In:* Proc. of Poplar Utilization Symp., ed. R.W. Neilson and C.F. McBride. Environ. Can., West. For. Prod Lab., Inf. Rep. VP-X-127, Vancouver, B.C. p. 220.

Note: P. F.--phenol formaldehyde; U. F.--urea formaldehyde.

TABLE 4

PRODUCT-RAW MATERIAL RELATIONSHIP OF COMPOSITE BOARDS

Product	Particle-fibre Configuration	Raw Material Input Form	Raw Material Supply Form	Species Preference
Insulation board Hardboard Medium-density fibreboard (industrial)	fibre	pulp chips sawdust shavings	roundwood millwaste forestry waste	softwood soft-hardwood almost any species
Particleboard industrial underlayment	particles semi-flakes fines semi-fibre	shavings sawdust plywood trim (chips)	millwaste	softwood (soft-hardwood)
Industrial flakeboard	flakes semi-flakes fines	roundwood plus: chips, shavings	roundwood plus: millwaste	softwood soft-hardwood
Structural flakeboard	flakes ("wafers") ("strands")	roundwood	roundwood	aspen (soft-hardwood, hard-hardwood, softwood)

Source: Vajda, P. 1974. Particleboard and fiberboard processes. *In:* Proc. of Poplar Utilization Symp., ed. R.W. Neilson and C.F. McBride. Environ. Can., West. For. Prod. Lab., Inf. Rep. VP-X-127, Vancouver, B.C. p. 221.

TABLE 5

ESTIMATED WAFERBOARD EXPANSION
IN NORTH AMERICA, 1979–1984

Year	Production	
	Mm^3	MMsf, 3/8-inch basis
1979	421.8	715.0
1980	634.2	1075.0
1981	1115.1	1890.0
1982	1613.6	2735.0
1983	1702.1	2885.0
1984	1702.1	2885.0

Source: Gummeson, V. 1979. Composite board challenges. *In:* Utilization of Western Canadian Hardwoods Symp. Proc., ed. J.A. McDonald and M.N. Carroll. Forintek Can. Corp., Spec. Pub. No. SP-2, Vancouver, B.C. p. 7.

continue to escalate with energy prices. However, demand is high and these higher costs have not discouraged investment(Table 5).

2.4.4 Fibre products

Pulp and paper are the major fibre products made from aspen, although hardboard and insulation are also included in the fibre product grouping. Trembling aspen has been used in pulp and paper for many years. The pulp and paper industry has traditionally been the largest user of aspen roundwood until the recent demand in the flakeboard industry. Only a small volume of the aspen in Western Canada is presently being used in pulping(Neilson 1975). Aspen pulp has many desirable papermaking qualities which include excellent sheet formation, softness, bulkiness, high opacity; it is easily bleached and has good printability. The low strength of 100% aspen pulp is due to its short fibres. Therefore aspen pulp usually requires blending with another species to increase paper strength. Major products include newsprint, tissue stock, book stock, magazine stock, and fine writing paper.

2.4.5 Minor products

Small amounts of aspen are used for various other products. Solid wood products include dowels, firewood, mine timbers, snow fencing, novelty items and export logs. Aspen is also utilized to make match splits, excelsior and animal

bedding(Koepke 1976). These products are presently using minor quantities of the resource, and with the possible exception of export logs, hold little potential for utilizing significant volumes of aspen.

2.5 Summary

The aspen resource occurs on a wide variety of sites and is extremely variable in phenotypic characteristics. The wood itself is fine-grained, light in colour and generally weak in strength. Harvesting costs for aspen are higher than softwoods due to high incidence of decay, heavy green weight and large amounts of crook and sweep. Aspen has proven suitable for utilization in lumber, veneer, composite panels, fibre products and other minor uses.

3. GENERAL CONCEPTS AND METHODOLOGY

This chapter contains a review of general concepts and methodology in using linear programming models to evaluate the utilization of aspen in Alberta. The discussion will address the benefits and limitations of using a linear programming model and give a general background for the development of the aspen model.

3.1 Benefits and limitations of linear programming

Linear programming analysis is a mathematical method which can allocate scarce resources among competing processes to obtain optimum effectiveness(Sitter 1969). Practically speaking, the method defines a single identifiable objective in the form of a linear equation, and determines the optimal solution of this objective using input restraints and alternate independent activities (Pearse and Sydneysmith 1966). The final solution gives the optimal use and real values of the resources and activities. An added benefit of linear programming analysis is that it provides information on how the optimum solution will change when input data are varied. Because of the interplay of intermediate products and activities in a complex production situation, optimum allocation of resources and critical points of change are very difficult to evaluate without a linear programming model. Thus, linear programming is an excellent tool in management decision-making.

Another benefit of linear programming analysis is the ability to quickly evaluate many types and sizes of systems once the model is constructed. For instance, the allocation of lumber to different types of resaws in a sawmill could be evaluated and optimized. A complex, integrated operation including pulp mills, sawmills and plywood production could also be analyzed. In either case, the linear programming solution would give the optimal utilization of resources and equipment in the system subject to the given constraints.

Although linear programming analysis is a very helpful tool with a wide variety of applications, there are several limitations to the method. The name itself implies an important limitation. Linear programming deals only with linear relationships. Therefore any activities or restraints with quadratic relationships cannot be evaluated unless they are reduced to a linear form. This factor limits the use of the concepts of probability and economies of scale in linear programming studies. The linear relationships also require that unit prices, production technology and unit costs are fixed.

The computer programs used to solve a linear programming model may also be a limitation. If the computer programs do not allow for integer variables(an extension of the linear programming model), precise results may be more difficult to obtain. The difficulty comes when fractional uses of resources or equipment do not represent practical solutions. For instance, purchasing only 26% of a pulp mill

is not feasible.

Finally, the effectiveness of linear programming analysis is probably most limited by the completeness and accuracy of the data input. Linear programming models are used to model and evaluate the essence of a system, not necessarily the reality. In so doing, certain areas of the physical system may not be included in the evaluation. Sometimes the areas that are evaluated tend to be ambiguous, making them difficult to define precisely. Because of these problems, linear programming should be considered a tool in the decision making process, and not a means of providing a definitive answer.

3.2 Background on developing the aspen model

The application of linear programming analysis to the aspen utilization problem has both advantages and disadvantages. One advantage is that this technique has the ability to analyze a wide range of resource and production options when determining the combinatons of most profitable operations. The problem with utilizing aspen in Alberta is not in lack of technical knowledge as much as in finding a combination of production options which are economically feasible. Another advantage of using linear programming analysis is the opportunity to determine the critical points of change, either in costs, prices or production, which will cause processes to be viable or unprofitable. Probably the

biggest disadvantage to applying linear programming analysis to aspen utilization is the lack of accurate data. The problem of old resource data has already been noted. Conversion data are also poor in certain areas of production(e.g., sawmills) simply because few people are manufacturing aspen products.

The model used in the analysis is constructed from the viewpoint of a large corporation seeking to diversify into potentially lucrative opportunities. Although modern technology in the forest products field will be employed to utilize aspen in the model, experimental or unproven systems will not be evaluated. Areas of production will include harvesting, hauling, lumber, pulp, plywood, particleboard, and waferboard. The model will describe options which have the potential of using relatively large amounts of the aspen resource. Only those products which have been or are presently being marketed will be included in the linear programming model. Re-manufacturing of the primary product, such as a furniture component plant, will not be considered at this time.

4. THE ASPEN MODEL

The previous chapter contains the description of concepts used to evaluate aspen utilization in Alberta. This chapter contains the specifics of the location; the wood resource, the production options and the products in the aspen reference model[5]. The equations used in the reference model assumed that the physical resources of wood, equipment, capital and labour are available for immediate use and that the construction of mills is instantaneous. All cost figures in the reference model are adjusted to 1980 dollars.

4.1 Location

The area chosen for evaluation of aspen utilization is located near Slave Lake, Alberta. The Slave Lake Forest has one of the highest proportions of aspen cover in all of Alberta's forest reserves(Alberta Energy and Natural Resources 1979). This region has traditionally been a centre for aspen utilization in Alberta having, at one time or another, an aspen stud mill, a veneer mill and a waferboard plant. Although the stud mill no longer exists and the veneer plant uses only a small amount of aspen, a newly expanded waferboard plant utilizes 100% aspen for its boards. Many government research projects on aspen

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[5]The model described in Chapters 4 and 5 will be referred to as the reference model. The optimal solution of the reference model will provide benchmark data for further analysis.

utilization have also been conducted in the Slave Lake area. These studies provided a considerable amount of the information utilized in the model.

4.2 Resource

The resource data used in the model are based upon the Alberta Forest Service(1971) publication "Present and Potential Poplar Utilization in the Province of Alberta." The data in this paper are old but they were the best available. The annual allowable cut of aspen on the Slave Lake Forest is 2,268,000 m^3. Fire loss deductions and a twenty-five percent deduction for cull are included in the 2,268,000 m^3 figure. However, 350,000 m^3 of previously committed timber allocations are not removed from this total.

As shown in Table 6, the forest was divided into 5 harvest areas based upon similar stocking characteristics. The sites are assumed to be made up of 80% trembling aspen and 20% balsam poplar, unless otherwise noted. Costs for sawlogs were \$0.47/m^3, which included \$.25/m^3 for the wood and \$.22/m^3 for reforestation(McDonald 1979). Pulpwood costs are a few cents cheaper, but to simplify the model all logs were considered sawlogs. An extra 7% was added to site volumes to account for the full-tree harvesting option(Keays 1971, Bailey 1973). Stumpage is the same with either option.

TABLE 6

DESCRIPTION OF HARVEST AREAS

Harvest Area	Slave Lake Forest Unit	Area Available (*ha*)	Stocking (m^3/ha)		Stumpage ($/*ha*)
			TL	FT	
1	S15	1910	73.4	78.5	34.50
2	S1,S4	5853	95.0	101.6	44.65
3	S3,S9,S10	4431	130.0	139.1	61.10
4	S5,S8	3876	161.0	172.3	75.67
5	S6,S12	2089	179.0	191.5	84.13

Note: TL—tree length; FT--full tree.

4.3 Harvesting

In the harvesting portion of the model, clearcutting is assumed using either manual or mechanical felling with wheeled skidding. Productivity and cost figures for these methods are given in Table 7. The model assumes all harvesting will be done by contract. A recent study by Alberta Energy and Natural Resources(1979) provided data the manual felling and road building costs. Feller-buncher costs are 25% higher than manual felling figures(Ryan 1979). The calculations for the data in Table 7 are found in Appendix 1.

4.4 Tree Size

The Alberta Forest Service(1971) divided the available timber volumes into two size classes by diameter at breast height(DBH). They were a 10.2-22.9 cm(4-9 in) class and a 25.4 cm(10 in) and greater class. One must accept two assumptions before these data can be utilized in the model. The first assumption is that only those trees in the 25.4 cm and greater class will be hauled to the mill. This assumption is erroneous, especially considering that the pulp, particleboard and waferboard mills could utilize smaller trees. However, the lack of better information necessitates this limitation. Secondly, an assumption is made that the 25.4 cm and greater volumes include tree sizes down to 22.9 cm(9 in). This assumption was made for the

TABLE 7

HARVESTING PRODUCTIVITY AND COST

Method	Productivity (m^3/hr)	Cost ($/hr)
TL Manual	5.66	87.22
TL Mechanical	2.80	53.94
FT Manual	8.41	129.60
FT Mechanical	4.36	83.98

Note: TL--tree length; FT--full tree

simplicity of applying the rough diameter distributions obtained by Bailey and Dobie(1977) to the available data. Size class distributions are shown in Appendix 2.

4.5 Hauling

Average hauling distance from the harvest sites to the town of Slave Lake is 145 km(90 mi) return(Alberta Energy and Natural Resources 1979). The common hauling practice in Alberta is either tree-length or full-tree. Tree-length hauling costs totalled $3.52/m^3$. An assumption is made that full-tree hauling would add 10% to the tree-length cost, making the cost for full-tree hauling $3.87/m^3$. Calculations for these costs are found in Appendix 3.

4.6 Processing

All mills are assumed to be located near the town of Slave Lake. Ample industrial property is available in the area for approximately $4942/ha($2000/A)(Holtby 1981). Five different configurations of processing facilities are included in the evaluation. The five were chosen because of their potential to use relatively large quantities of aspen. The facilities included are:

1. four sawmills,
2. a pulp mill,
3. a particleboard mill,
4. a plywood mill, and

5. a waferboard mill.

4.6.1 Sawmills

The model includes the option of a scrag mill or a twin band mill to produce both factory and construction lumber products. Factory lumber is used in items such as furniture and is graded by hardwood lumber standards. Construction lumber, on the other hand, is graded on softwood structural building standards. Table 8 describes the different assumptions of each mill. The scrag sawmill and twin band sawmill were used in the model because pertinent data were available for utilizing aspen in these systems. Studies by Leach and Gillies(1972), Bailey and Dobie(1977), and Boywer(1974) used 2.54 m(100 in) sawlogs to reduce cull but related lumber recovery to tree DBH rather than sawlog size. The sawmills in the model, therefore, produce 2.44 m(8 ft) lumber and base lumber conversion factors on DBH classes. Appendix 4 includes an elaboration on the mills and their products.

4.6.2 Pulp mill

Market pulp production in the model uses the chemi-mechanical process. Production and cost data for the pulp operation were obtained from Woodbridge Reed and Associates(1981). The mill has a capacity of 425 air dry metric ton(admt) per day utilizing a mixture of 50% aspen and 50% spruce. Woodbridge *et.al.*(1981) provided the

TABLE 8

DESCRIPTION OF THE SAWMILLS

Mill Name	Equipment	Products	Average Lumber Recovery (%)	Capacity (m^3)	Capacity (MMfbm)
Stud	2-saw scrag, chipping edger	studs, boards	57.0	42250	18.0
Dim.	2-saw scrag, chipping edger	dimension, boards	57.0	42250	18.0
Board	2-saw scrag, chipping edger	factory lumber	47.5	38000	16.
Twin	twin band, 2 vertical resaws	factory lumber	45.8	45312	19

Note: Lumber recovery percentages converted to lumber recovery factors are: 57% = 6.8 fbm/ft^3, 47.5% = 5.7 fbm/ft^3 and 45.8% = 5.5 fbm/ft^3.

production and cost data for the model. Chips are available for pulping from both roundwood and sawmill or plywood residue. The spruce chip component is purchased at $35/bone dry unit(BDU). The pulp yield of aspen is only 31.45% due to the high quality of chips required by the process. Total capital cost of the mill is over $100 million with operating costs of $170.50/admt. A further breakdown of pulping figures is included in Appendix 5.

4.6.3 Particleboard mill

Particleboard production in the model is based upon the mill described by Bowyer(1974). The operation has an annual capacity of 100,359 m^3(56.7 MMsf, 3/8-inch basis). The mill converts 78.9% of the raw material input into a three-layer board with a density of 640 kg/m^3(40 lbs/ft^3). Chips are again available from roundwood and mill residue. Four board thicknesses from 9 mm(3/8 in) to 19 mm(3/4 in) were arbitrarily chosen for production sizes. A product mix was not specified, thus allowing the model to choose the most profitable thickness. The particleboard cost data are outlined in Appendix 8.

4.6.4 Waferboard mill

Waferboard production and cost information was obtained from Columbia Engineering International Ltd.(1981). The mill has an annual capacity of 141,600 m^3(160 MMsf,3/8-inch basis) using a 2.44 m(8 ft) by 4.88 m(16 ft) twelve opening

press. The assumption was made that wafers are generated only from roundwood. Five different thicknesses of waferboard were arbitrarily chosen to describe options for production. The capital cost of the operation exceeds $37.5 million, with operating costs of $76.55/m³. Appendix 6 shows the details of the waferboard costs and conversion factors.

4.6.5 Plywood mill

The equations to describe the production of aspen plywood were not as straightforward as those for the other mills. Conversion data for specific log sizes were available in Boywer(1974) but resource information refers to only tree sizes by DBH class. Using data from Leach and Gillies(1972), Bailey(1973) and Bailey and Dobie(1977), a log mix was derived for the various tree class sizes(see Appendix 7). A summary of this mix is found in Table 9. Cull material is chipped for pulp or particleboard production at a cost of $7.94/m³(see Appendix 5). Bowyer's(1974) technique was then utilized to determine the volume of dry veneer, core, drying loss and rounding and trimming for the different log classes shown in Table 10 and developed in Appendix 7. Capital and manufacturing costs of the 27,450 m³/yr plywood operation were also obtained from Bowyer(1974).

TABLE 9

SUMMARY OF PLYWOOD LOG MIX

Tree Size Class (cm)	Percent Of Log Sizes				
	20 cm	28 cm	36 cm	43 cm	Cull
23	25.00	. . .	. . .	. . .	. . .
30	37.50	18.75	. . .	. . .	43.75
38	44.40	33.30	16.60	. . .	5.70
46	10.00	40.00	35.00	15.00	0.00

TABLE 10

BREAKDOWN OF PLYWOOD LOGS

Log Size (cm)	Dry Veneer (%)	Core (%)	Rounding and Trim (%)	Drying (%)
20	43	27	19	11
28	49	15	25	11
36	53	9	27	11
43	55	6	28	11

4.7 Chips and residue

The chip and residue component of production is handled in a number of different ways. Chips are generated from lumber production, plywood production or from roundwood. The chips produced at the sawmills and plywood facility can be utilized for pulp and particleboard at zero cost. An assumption was made that other chip markets are not presently available. Except for the waferboard operation, the mills in the model do not generate any of their own energy requirements from hogfuel, plywood trim or rounding material[6]. All mills, however, were assumed to utilize only barked wood. Market prices were obtained for hogfuel and plywood residue in order to quantify the amount of this material in the optimal solution. The hogfuel price is $6.11/m^3 and the plywood trim and rounding material price is $8.14/m^3(Columbia Engineering International Ltd. 1981).

4.8 Products and prices

Some of the products which can be manufactured in the model have already been listed in the individual mill discussions. A complete list of potential products and their prices is found in Table 11. The stud and dimension prices shown were obtained by subtracting $10.00/Mfbm from the Madison's Canadian Lumber Reporter(Friesen 1981) for

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[6]Although plywood trim and rounding residue can be used in particleboard furnish, this material is not made available for that use in order to simplify the model.

TABLE 11

PRODUCT OPTIONS AND PRICES
USED IN REFERENCE MODEL

Mill	Product Grade or Thickness	Price
stud	studs	$149.00/Mfbm
	econ. stud	85.00
stud and dimension	select board	$305.00/Mfbm
	const. board	200.00
	std. board	195.00
	util. board	120.00
	econ. board	85.00
dimension	construction	$152.00/Mfbm
	standard	152.00
	utility	103.00
	economy	85.00
twin and board	#1&BTR board	$425.00/Mfbm
	#2A board	200.00
	#2B board	200.00
	#3 board	150.00
pulp	pulp	$510.00/admt
particleboard	9 mm	$229.32/$m^3$
	13 mm	211.86
	16 mm	211.86
	19 mm	203.04
waferboard	6 mm	$317.80/$m^3$
	8 mm	296.61
	9 mm	264.83
	11 mm	248.18
	16 mm T&G	286.02
plywood	6 mm	$557.94/$m^3$
	13 mm	337.46
	19 mm	284.04

spruce-pine-fir. The $10.00 discount is a measure of market reluctance to use aspen lumber when compared to alternatives(Karim 1981). Prices on factory lumber were obtained from Nielson(1979). The pulp price came from Woodbridge *et.al.* (1981). MacMillian Bloedel Building Materials Ltd.(1981) supplied the waferboard and particleboard prices, and plywood prices were obtained through reducing retail prices(University of Alberta 1981) by 12%.

4.9 Capital and operating costs

In order to analyze the optimum combination of activities for harvesting, milling and marketing aspen, financial requirements were not limited. All operating costs are deducted from the profit as they occur; however, 24% interest is charged for the use of the money. Likewise, depreciation is deducted when mills are utilized, and 12% interest is charged on capital purchases.

5. THE LINEAR PROGRAMMING MATRIX

The content of this chapter outlines the arrangement of the information discussed in Chapter 4 into a linear programming matrix format. The matrix will be referred to as the reference matrix. The optimal solution of the matrix will yield baseline data for sensitivity analysis of the model. The reference matrix consists of the linear objective function plus a set of constraining equations. The constraining equations define the limits and inter-relationships of the variables in the objective function. The matrix can be separated into the general sections of harvesting, milling, marketing and resource limits, as illustrated in Figure 2. The complete matrix is found in Appendix 9.

5.1 The objective function

The objective function in the aspen reference matrix calculates net profit. The function evaluates 127 variables and their associated coefficients. Variables indicate the level of use of a paticular activity. The associated coefficients take into account costs in the harvesting and milling sections and the returns on various products in the marketing section.

$$
\begin{array}{llllll}
Z_{max} = & Hw & + & My & + & Sx \\
\text{subject to:} & & & & & \\
& Aw & & & & = R_1 \\
& Bw & & Cy & & = R_2 \\
& & & Dy & Ex & = 0
\end{array}
$$

where:

Z_{max} = the objective function to be maximized.

H = row vector of coefficients associated with the cost of harvesting(1 X 56).

M = row vector of coefficients associated with the cost of milling(1 X 31).

S = row vector of coefficients associated with the returns of marketing(1 X 39).

w = column vector of harvesting variables(38 X 1).

y = column vector of milling variables(68 X 1).

x = column vector of marketing variables(29 X 1).

A = matrix of harvesting coefficients(24 X 30).

B = matrix of production coefficients(14 X 26).

C = matrix of wood requirement coefficients for mills(39 X 31).

D = matrix of coefficients for product output(29 X 8).

E = matrix of coefficients to market products(29 X 39).

R_1 = column vector of resource limitations on harvesting(24 X 1).

R_2 = column vector of resource limitations on milling(39 X 1).

Figure 2. General equations of model matrix

5.2 Harvesting section

The harvesting section of the reference matrix contains resource limitations, available felling options and hauling variables.

5.2.1 Resource limitations

Ten variables in the matrix deal with the aspen resource in the Slave Lake Forest. Although only five potential harvest areas are available in the model, ten variables are necessary to define stand volumes using tree-length or full-tree harvesting methods. The units of the resource variables are hectares. Stand volumes on each area are shown in Table 6.

The resource variables are limited in two ways. The first limits the number of hectares that can be harvested in each area. The second limits the volume removed from the whole forest by the annual allowable cut. The allowable cut from the individual harvest areas is determined using tree-length volumes. The extra volume associated with full-tree harvesting is included when volumes are transferred to the felling options.

5.2.2 Felling options

The volume of trees from the harvest areas is transferred to the felling variables through transfer equations. Four felling variables are needed for each harvest area. Two of the variables represent tree-length

felling. The other two represent full-tree felling. Felling productivity coefficients(Table 7) convert tree volumes into the felling variable units(hours). Felling costs are deducted from the objective function as a specific variable is utilized.

The equations used to transfer quantities out of the felling variables perform two functions. The first function uses conversion figures to calculate tree volumes(m^3). Secondly, tree size classes are delinated by utilizing an equation for each size class. An explanation of the method used to determine these transfer coefficients is found in Appendix 2.

5.2.3 Hauling

Tree volumes are transferred from the felling variables into hauling variables utilizing eight equations. These equations account for four tree size classes and keep tree-length and full-tree volumes distinct. There are a total of twenty-six hauling variables. The function of these variables is to calculate tree volumes that could be utilized at the different mills. A small percentage of the tree volume transferred into all hauling variables is subsequently transferred to a variable which accounts for tree bark. The full-tree volumes also have a branch and top percentage removed. The remaining percentage of tree volume is transferred to the milling section.

In the sawmill and plywood hauling variables, the integrity of tree sizes was maintained to account for recovery differences with respect to size class. Usable tree volumes in the chip hauling variables were transferred to the pulp and particleboard mills. The volumes of wood transferred to the waferboard mill were converted directly into waferboard by the hauling variable coefficients. The treatment of tree volumes in the hauling variables are calculated for sawmills, chips, waferboard and plywood in Appendicies 4, 5, 6 and 7, respectively.

5.3 Milling section

The variables in the milling section of the reference matrix represent the various processing facilities available to the hypothetical firm. The milling variables take into account conversion factors, operating costs, capital costs and depreciation.

5.3.1 Lumber, pulp, particleboard and waferboard production

The arrangement of the variables representing the sawmills, pulp mill, particleboard mill and waferboard mill is similar. Two variables are used for each mill. The stud sawmill variables will illustrate the function of the two variables. Tree volumes separated by size class are transferred into the first stud mill variable from the hauling variables. The coefficients of these transfer

equations in the stud mill column are lumber recovery figures. Operating costs are deducted from the objective function as the first stud mill variable is utilized.

The volume of lumber manufactured is then transferred to the second stud mill variable. This variable represents the fixed cost portion of the sawmill. Deductions for depreciation are taken from the objective function and capital to build the mill is transferred from the stud capital-lending variable. The volume of lumber according to grade(see Appendix 4) is subsequently transferred to the marketing section.

5.3.2 Plywood production

The modelling of the plywood mill required five variables. Veneer recovery varies with log size. Because the hauled material is designated by DBH class, additional transfer equations were necessary to represent the separation of tree volumes into log size classes, as seen in Appendix 7. The volume of logs in each class is subsequently transferred into four variables which account for plywood production. Operating costs are deducted by these variables. The plywood manufactured is then transferred to a single variable which is used to calculate the depreciation, the amount of capital required to buy the mill and the volume of plywood available to the marketing section.

5.3.3 Other activities

The milling section of the matrix also includes variables representing the volume of chips, the quantity of money borrowed and tax and advertising costs. The chip variables represent the volume of chips resulting from the chipping of log-ends in plywood log production. The chips can be utilized for pulp and particleboard production or they can be sold on the open market. The money variables deduct interest charges from the objective function for both operating and capital costs. The tax and advertising variables are used to deduct 2.75% of the value of gross sales from the revenue to pay property taxes and advertising costs.

5.4 Marketing section

The marketing section of the matrix calculates the revenue in the model. The variables in this section represent eleven grades of construction lumber, four grades of factory lumber, market pulp, four thicknesses of particleboard, five thicknesses of waferboard, three thicknesses of plywood, chips, hogfuel and plywood trimming and rounding residue. Sawmill variables transfer a prescribed grade mix into the lumber marketing variables utilizing a number of transfer equations. The volume of particleboard produced is transferred by one equation. This volume can be utilized by any of the four particleboard

thickness variables which results in the most profitable product mix. The transfer of waferboard and plywood production to the marketing section is modelled in the same manner. The hogfuel and trimming and rounding variables were included for reference purposes only.

5.5 Resource limitations

The resource limitations section defines the variable limits in the reference matrix. Most coefficients in this section are zero because many equations are transfer equations. A balance equation is used to transfer values from one variable to another. For instance, the transfer equation from the variable representing particleboard production(PARTMIL) to the variable representing capacity of the particleboard mill(PARTCAP) is:

$$-0.789 \times PARTMIL + 1.0 \times PARTCAP \leq 0$$

For this equation to be true, the activity level of the PARTMIL variable(i.e. m^3 of production) must be matched with the activity level of the PARTCAP variable(i.e. m^3 of plant capacity).

The equations that have non-zero coefficients represent physical resource limits. The equations limit annual allowable cut, land area available for harvest and production facility capacities. These resource limits are shown in Table 12.

TABLE 12

UPPER LIMITS ON ACTIVITIES IN THE MATRIX

Activity	Limit
annual allowable cut	2,268,000 m^3
harvest area 1	1,910 ha
harvest area 2	5,853 ha
harvest area 3	4,431 ha
harvest area 4	3,876 ha
harvest area 5	2,089 ha
stud and dimension sawmill	42,250 m^3
twin sawmill	45,312 m^3
board sawmill	38,000 m^3
pulp mill	157,500 admt
particleboard mill	100,539 m^3
waferboard mill	141,600 m^3
plywood mill	27,450 m^3

6. RESULTS OF THE ANALYSIS

The optimal solution of the aspen reference model was found using the linear programming package[7] on the Amdal 470 v/8 computer at the University of Alberta. Various techniques of sensitivity analysis were subsequently utilized on the reference matrix to demonstrate the effect of model variation.

6.1 The optimal solution of the reference matrix

The optimal solution using the coefficients in the reference matrix shows that a net profit of nearly $25.0 million would be realized. Operating expenses would total $49.2 million and capital costs would be $55.6 million. The profit was derived from selling lumber, particleboard, waferboard and plywood. Table 13 gives the summary of major solution variables. The complete solution is found in Appendix 10.

6.1.1 Harvesting results

A total of 937,062 m^3 of aspen would be harvested annually using activities in the optimal solution. This amounts to 41% of the deciduous allowable cut on the Slave Lake Forest. The model utilized all the land available in harvest area 5 and ninety percent of the land in harvest

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[7] The Mathmatical Programming System/360(360A-CO-14X) Linear and Separable Programming package supplied by International Business Machines Corporation was used to solve the matrix.

TABLE 13

OPTIMUM SOLUTION OF REFERENCE MODEL

Model Variable		Limit of Utilization	Activity Level
Z_{max} (\$)		...	24,952,490
operating cost (\$)		...	48,360,606
capital cost (\$)		...	55,585,223
harvesting	area 1 (*ha*)	1,910	...
	area 2 (*ha*)	5,853	...
	area 3 (*ha*)	4,431	...
	area 4 (*ha*)	3,876	3,496
	area 5 (*ha*)	2,089	2,089
hauling	sawlogs (m^3)	...	218,067
	chips (m^3)	...	...
	waferboard (m^3)	...	342,615
	plywood (m^3)	...	64,880
mills	stud (m^3)	42,250	42,250
	dimension (m^3)	42,250	...
	twin (m^3)	45,312	...
	board (m^3)	38,000	38,000
	pulp (*admt*)	157,500	...
	particleboard (m^3)	100,359	100,359
	waferboard (m^3)	141,600	141,600
	plywood (m^3)	27,450	27,450

area 4. Tree-length and full-tree harvesting methods are employed using manual labour for felling. The sawmill and plywood mill receive both tree-length and full-tree material. The waferboard mill uses only the full-tree component. Roundwood is not chipped. Eighty-seven percent of the wood directed to the plywood mill is in the 46 cm DBH size class.

6.1.2 Mill utilization and products

The optimal solution includes variables representing two sawmills, the particleboard mill, the waferboard mill and the plywood mill. All mills operate at 100% capacity. The chips required for particleboard production come from the sawmills and plywood mill. The products sold by the mills include construction and factory lumber, 9 mm(3/8 in) sheets of particleboard and 6 mm(1/4 in) thicknesses of waferboard and plywood. Table 14 shows the quantity of products which were manufactured. The volume of residue generated by the model totalled 6,146 m³ of hogfuel and 13,833 m³ of plywood trim and rounding.

6.2 Variations in harvesting

Sensitivity analysis in the harvesting section of the model concentrated on the variables associated with the wood resource and harvesting methods. The effects of stand variation on the optimal solution were analyzed and the

TABLE 14

PRODUCTS IN OPTIMAL SOLUTION OF REFERENCE MODEL

Product	Grade or Thickness	Production
	select	901 Mfbm
construction lumber (boards)	construction	382
	standard	546
	utility	355
	economy	27
construction lumber (studs)	stud	21,767 Mfbm
	economy stud	3,359
	#1&BTR	3,270 Mfbm
factory lumber	#2A	4,088
	#2B	4,088
	#3	4,905
particleboard	9 mm	100,359 m^3
waferboard	6 mm	141,600 m^3
plywood	6 mm	27,450 m^3

critical costs of harvesting methods on area 5 were identified.

6.2.1 The resource

The aspen stand data used in the reference model are evauated in this section. The cost of aspen stumpage accounts for less than 1% of the total operating cost of the optimal solution. Variation of these costs in the model would provide little relevant information on aspen utilization. The assumption that all stands contain the same mix of tree sizes effectively eliminates the significance of varying volume statistics on the harvest areas. Increasing or decreasing the volume stand statistics areas will cause the model to choose the areas with the highest stand volumes. However, the effect of tree size on the optimal solution can be evaluated by changing the DBH size distributions.

The tree size distributions in the reference model were varied in two ways. The DBH size mix of the reference model has almost one-half of the volume of the stands in trees 38 cm and greater. Only 14.9% of the volume is assumed to be in the 23 cm DBH class. The first variation of the model changed the mix on area 5 to forty percent of the volume in the 23 cm class, thirty-five percent in the 30 cm class, fifteen percent in the 38 cm and ten percent in the 46 cm class. The tree size mix was not altered on any of the other harvest areas. The second variation changed the DBH classes

in areas 4 and 5 to the 40/35/15/10 mix.

The effects of the mix variations on the optimal solution of the reference matrix are tabulated in Table 15. In variation 1, the mix changes did not effect the optimal mill production of the reference model. The new size class mix on area 5 caused the harvesting of six more hectares of area 4 and some distribution changes of tree sizes and volumes delivered to the mills. The optimal solution of the reference matrix was further altered in variation 2 where tree sizes on areas 4 and 5 were adjusted. Mill production included all the mills of the reference solution, but the stud mill ran at 92% of capacity instead of the 100% capacity utilized in the optimal solution. The number of hectares harvested on area 4 was reduced and 1098 hectares of area 2 was cut. The hauling statistics indicate that the tree volumes used by the different mills changed as tree size mix changed.

The conclusion from evaluating size class variation is that size class distribution has little effect on production. The reason for this lies in the integrated system of mills. Various tree sizes can be brought into the facility and distributed in an optimal fashion to the mills. Therefore, sufficient volumes of trees are more critical to aspen utilization than tree size.

TABLE 15

VARYING TREE SIZE DISTRIBUTION IN THE REFERENCE MODEL

Model Variable		Reference Matrix	Variation 1	Variation 2
Z_{max} ($)		24,952,490	24,917,680	24,714,596
harvesting	area 2 (ha)	...	...	1,098
	area 4 (ha)	3,496	3,502	2,851
	area 5 (ha)	2,089	2,089	2,089
hauling	sawlogs (m^3)	218,067	217,382	208,131
	waferboard (m^3)	342,615	344,306	345,928
	plywood (m^3)	64,880	64,676	69,561
mills	stud (m^3)	42,250	42,250	38,771
	board (m^3)	38,000	38,000	38,000
	particleboard (m^3)	100,359	100,359	100,359
	waferboard (m^3)	141,600	141,600	141,600
	plywood (m^3)	27,450	27,450	27,450

6.2.2 Harvesting methods

Harvesting methods can be evaluated in the model using the range report. The optimal solution of the reference matrix utilizes the full-tree, manual felling option for harvesting area 5. Tree-length harvesting would be employed on this area if full-tree harvesting costs would increase by $0.50/hr. A lowering of the cost of tree-length, manual harvesting from $87.22/hr to $86.71/hr would produce the same change. Switching from manual to mechanical methods of harvesting would require full-tree, mechanical harvesting costs to drop from $83.98/hr to $63.13/hr. Changing to strictly tree-length harvesting would not add significantly to the cost of harvesting aspen, but a switch to mechanical felling would have a significant cost impact.

6.3 Variation of the mills

The sensitivity of the reference model to changes in mill cost is examined in this section.

6.3.1 Mill operating costs

The effect of increased operating costs for a mill in the reference model can be evaluated using the range report. The report shows the highest operating cost a mill can have before the variables in the optimal solution will change. Table 16 records the critical upper costs for the mills. An operating cost increase of $5.00/m^3 produced at the stud

TABLE 16

UPPER LIMIT OF MILL OPERATING COSTS BEFORE SOLUTION CHANGE

Mill	Operating Cost($/m^3$)	
	reference model	upper limit
stud	15.33	20.23
board	17.06	52.13
particleboard	52.33	105.89
waferboard	76.55	135.62
plywood 1	49.08	64.31
plywood 2	55.92	118.15
plywood 3	60.49	69.01
plywood 4	62.77	69.94

sawmill will cause the dimension sawmill to enter the solution. The board mill ceases production when costs escalate to $52.13/m^3$ and the particleboard operation is profitable up to an operating cost of $105.89. The operating cost of the waferboard mill can increase over $59.00/m^3$ produced before waferboard will no longer be manufactured in the reference model. Production of waferboard will decrease at a rate of 788 m^3 per dollar as this cost increases. The cost figures for the plywood mills give an indication of relative sensitivity of the model to bolt size. Trees will be hauled for chips when the cost of veneer production from 28 cm bolts increases to $64.31/m^3$. The type and size of trees delivered to plywood mills 2,3 and 4 are changed when the upper cost limits are attained in these operations. With the exception of the stud sawmill and plywood mills 3 and 4, the operating costs of mills in the optimal solution could increase $15.00/unit and not effect the mill combination in the optimal solution.

6.3.2 Realignment of mill operating and capital costs

The selection process of mill variables in the optimal solution of the reference matrix first chooses the mill operating cost variable. The capital cost variable enters the solution immediately after the operating cost variable. Under this system, the model calculates capital costs for only the mill capacity needed to support production levels(i.e. the model assumes linear relations between mill

cost and capacity). This was not a problem in the optimal solution of the reference model because all mills operated at full capacity. The analysis of this section utilized separable programming to alter the pulp and particleboard mills. These changes described the situation where a mill of specified capacity must be built before production would begin.

Four evaluations of the altered matrix were conducted. The first run allowed the model to find the optimal solution utilizing any combination of mills. The second evaluation forced the model to include the pulp mill, but did not require the production of pulp. Similarly, the particleboard mill was forced into the solution in the third run. The fourth evaluation forced the model to include both the pulp mill and the particleboard mill in the solution. The results of the evaluation are shown in Table 17.

The results of the first evaluation showed that neither the pulp mill nor the particleboard mill entered the solution. These results contradict the optimal solution of the reference matrix where the particleboard mill operates at full capacity. The reason for this problem orginates in the mathematical procedures utilized to solve linear programming. These procedures can generate erroneous data because a local optimum. The results of the first analysis are due to a local optimum.

The second and third analyses show profitable operations when either the pulp mill or the particleboard

TABLE 17

SEPERABLE PROGRAMMING OF PULP AND PARTICLEBOARD PRODUCTION IN MODEL

Model Variable		Mill forced into Solution			
		none	pulp	particlebd	both
Z_{max} ($)		16,109,106	6,674,818	27,212,617	-4,209,273
harvesting	area 2 (*ha*)	...	5,853	...	...
	area 3 (*ha*)	...	1,355	...	...
	area 4 (*ha*)	1,308	3,876	3,498	3,502
	area 5 (*ha*)	2,089	2,089	2,089	2,089
hauling	sawlogs (m^3)	...	215,376	218,025	217,970
	chips (m^3)	...	470,215	...	...
	waferboard (m^3)	342,813	338,245	342,608	342,599
	plywood (m^3)	60,761	91,383	65,150	65,483
mills	stud (m^3)	...	42,250	42,250	42,250
	board (m^3)	...	38,000	38,000	38,000
	pulp (*admt*)	...	157,500	...	100
	particleboard (m^3)	...	...	100,359	100,359
	waferboard (m^3)	141,600	141,600	141,600	141,600
	plywood (m^3)	27,450	27,450	27,450	27,450

mill is forced into the solution. In both cases, the optimal solution builds the mill and operates it at full capacity. The $20.0 million difference in profit between runs two and three clearly shows the advantage of operating an aspen particleboard mill rather than a pulp mill. A loss of $5.3 million occurs when both mills are forced to be built. The loss is incurred because a large capital investment for the pulp mill must be made even though it is not profitable.

The conclusion to the realignments analysis indicates that either a pulp or particleboard mill could operate profitably in an integrated aspen facility. The facility with a particleboard mill is considerably more profitable than one with a pulp mill. An aspen utilization facility could not operate with both a pulp and particleboard mill.

6.4 Variation of product prices

The effect of product price change on the optimal solution of the aspen model is evaluated in this section.

6.4.1 Particleboard, waferboard and plywood variation

Particleboard prices, waferboard prices and plywood prices were varied using parametric programming techniques. The price of particleboard was lowered to $129.32/m^3. Waferboard and plywood prices were reduced to $217.80/m^3 and $235.94/m^3, respectively. Optimal solutions were calculated as product prices were incremented by $25.00 and other model

coefficients remained constant. This was done in order to determine when production of the product became profitable. Another analysis evaluated the interaction between the three products by incrementing their prices simultaneously.

The first evaluation analyzed particleboard prices, as summarized in Table 18. The particleboard mill cannot operate at a profit when the product price is $\$129.32/m^3$. When the price of particleboard is incremented to $\$154.32/m^3$, the particleboard mill and stud mill enter the solution and operate at full capacity. Table 19 records the critical prices for waferboard production. The mill operates at 26% of its capacity when the selling price of waferboard is $\$242.80/m^3$. The waferboard mill runs at full capacity when the waferboard price is $\$292.80/m^3$. Similarly, the plywood mill enters the optimal solution at $\$260.94/m^3$, but does not reach full mill capacity until the price is $\$285.94/m^3$, as seen in Table 20.

The final price evaluation using parametic procedures simultaneously incremented the particleboard, waferboard and plywood prices. Particleboard prices started at $\$104.32/m^3$, waferboard prices at $\$192.80/m^3$ and plywood prices at $\$235.94/m^3$. The results of the analysis show that aspen utilization is not profitable at the starting prices(Table 21). The first increment of $\$25.00/m^3$ caused the board sawmill, the pulp mill and the plywood mill to enter the solution. The chips produced from the manufacturing of lumber and plywood are sufficient for the pulp mill to

TABLE 18

EFFECT OF PARTICLEBOARD PRICE
VARIATION ON THE OPTIMAL SOLUTION

Model Variable		Particleboard Price ($\$/m^3$)	
		129.32	154.32
Z_{max} ($)		18,786,774	20,543,997
harvesting	area 4 (ha)	2,226	3,496
	area 5 (ha)	2,089	2,089
hauling	sawlogs (m^3)	93,849	218,067
	waferboard (m^3)	342,717	342,615
	plywood (m^3)	60,761	64,880
mills	stud (m^3)	...	42,250
	board (m^3)	38,000	38,000
	pulp ($admt$)	19,499	...
	particleboard (m^3)	...	100,359
	waferboard (m^3)	141,600	141,600
	plywood (m^3)	27,450	27,450

TABLE 19

EFFECT OF WAFERBOARD PRICE VARIATION ON THE OPTIMAL SOLUTION

	Model Variable	Waferboard Price ($\$/m^3$)		
		217.80	242.80	292.80
Z_{max} (\$)		17,809,461	17,944,621	24,530,922
harvesting	area 4 (*ha*)	32	1,119	3,496
	area 5 (*ha*)	2,089	2,089	2,089
hauling	sawlogs (m^3)	150,514	218,996	218,067
	chips (m^3)	15,200	...	...
	waferboard (m^3)	...	90,034	342,615
	plywood (m^3)	85,863	64,650	64,880
mills	stud (m^3)	20,013	41,789	42,250
	board (m^3)	38,000	38,000	38,000
	particleboard (m^3)	100,359	100,359	100,359
	waferboard (m^3)	...	37,084	141,600
	plywood (m^3)	27,450	27,450	27,450

TABLE 20

EFFECT OF PLYWOOD PRICE VARIATION ON THE OPTIMAL SOLUTION

Model Variable		Plywood Price($/$m^3$) 235.94	260.94	285.94
Z_{max}($)		19,951,651	20,033,620	20,604,522
harvesting	area 4(ha)	3,007	3,085	3,496
	area 5(ha)	2,089	2,089	2,089
hauling	sawlogs(m^3)	218,722	217,111	218,067
	chips(m^3)	14,802	...	...
	waferboard(m^3)	341,483	341,630	342,615
	plywood(m^3)	...	20,793	64,880
mills	stud(m^3)	42,250	42,250	42,250
	board(m^3)	38,000	38,000	38,000
	particleboard(m^3)	100,359	100,359	100,359
	waferboard(m^3)	141,600	141,600	141,600
	plywood(m^3)	...	4,847	27,450

TABLE 21

PARTICLEBOARD, WAFERBOARD AND PLYWOOD PRICE VARIATION IN THE REFERENCE MODEL

Model Variable		Initial Price	Increment 1	Increment 2
Z_{max} ($)		...	206,976	2,951,297
harvesting	area 4 (*ha*)	...	...	1,119
	area 5 (*ha*)	...	1,373	2,089
hauling	sawlogs (m^3)	...	92,141	218,996
	waferboard (m^3)	...	...	90,034
	plywood (m^3)	...	70,081	64,650
mills	stud (m^3)	...	...	41,789
	board (m^3)	...	38,000	38,000
	pulp (*admt*)	...	25,394	...
	particleboard (m^3)	...	...	100,359
	waferboard (m^3)	...	...	37,084
	plywood (m^3)	...	22,652	27,450

Note: Initial price was particleboard = \$104.32/m^3, waferboard = \$192.80/m^3 and plywood = \$235.94/m^3. Prices were incremented in \$25.00 units.

operate at 16% of capacity. The next price increment brings the stud mill, the particleboard mill and the waferboard mill into the solution. The pulp mill is no longer profitable at this increment. Further increments of prices do not alter the solution.

Analysis of price variation revealed additional information on aspen utilization besides critical production price data. The final analysis illustrates that aspen utilization can only be profitable with an integrated system of mills. The minimum number of mills appears to be three, as shown in Table 21, when the plywood, pulp and board mills are in the solution. Another interesting point is that plywood production becomes profitable at a lower price in the final analysis than when prices are individually incremented. This is due to the lack of competition for tree volumes in the final analysis. The profitable operation of the stud mill is directly linked to the utilization of stud chips in the particleboard mill. This is illustrated in Tables 18 and 21 by the stud mill entering the solution when the particleboard operation became profitable. Likewise, in Table 20, chips from the manufacture of plywood replace the chips produced from roundwood when plywood production is profitable.

6.4.2 Chip, pulp and stud prices

The effects of changes in the price of chips, pulp and studs were evaluated using a range report. Chips in the reference model have the option of being utilized in the pulp mill and the particleboard mill or being sold on the open market. The optimal solution showed that all chips would be used in particleboard production. The market price for chips needs to be at a minimum of $114.00/BDU before chips could be sold at a profit. The high price of market chips indicates the value of these chips within the model. The price for pulp must increase from $510.00/admt to $564.43/admt before pulp production becomes profitable. Stud prices can drop only $9.52/Mfbm to $139.48/Mfbm before dimension lumber becomes more profitable to produce. This shows that an aspen sawmill producing studs should have the flexibility to move into the dimension lumber market.

7. SUMMARY AND RECOMMENDATION

The forest resource in Alberta contains 680 MMm^3 of deciduous, merchantable timber. Although the net annual allowable cut for this timber is 11.7 MMm^3, only 1% of this amount is utilized every year. This study showed that the utilization of Alberta's untapped deciduous resource is both possible and profitable.

7.1 Summary

The aspen utilization model developed in this analysis showed that an integrated system of mills is necessary to use aspen. The optimal system includes sawmill, particleboard, waferboard and plywood facilities. The model showed tree-length harvesting of aspen does not have a significant cost difference from the full-tree method. However, a switch from manual felling to mechanical methods would greatly affect harvesting cost. The volume of aspen in a stand was determined to be more critical to utilization than the tree size distribution. This is due to the ability of the integrated system to optimally direct incoming tree volumes to the different mills. Maximum profit is attained in the model when chip residue can be utilized. Either a particleboard mill or pulp mill can be used in this regard, but the particleboard mill is more profitable. The analysis also showed that sawmills must be versatile in their ability to meet market demands.

7.2 Recommendation for validation

The conclusions derived from this analysis are based upon the assumptions and the data used in the model. The results could vary significantly when either the assumptions or the data are altered. The sensitivity analysis performed in the study illustrated the procedure that would be used to validate other groups of coefficients in the model.

This analysis identified three areas of evaluation which need further study. The first area deals with the aspen resource data. Accurate information needs to be obtained on stand volumes, tree sizes and decay percentages. The analysis showed that total harvest area volume was more important than tree size. However, both volume and tree size information is critical to utilization. The amount of decay will also have an effect on product conversion factors, particularly plywood. The second area of evaluation is that of mill data. Current mill costs and utilization techniques need to be applied to the aspen utilization problem. Other types of processing mills should also be introduced. Finally, cost and productivity data for harvesting and hauling of aspen need to be evaluated and validated.

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APPENDIX 1. HARVESTING APPENDIX

The harvesting appendix is divided into two sections which include felling and skidding productivity and harvesting costs.

A. Felling and skidding productivity

The harvesting options in the model include the methods of tree-length or full-tree harvesting. The trees were all skidded by wheeled skidder. Productivity data for tree-length harvesting using a three-man crew were taken from Leech and Gillies(1972). The productivity of full-tree harvesting with a three-man crew was derived by increasing the tree-length productivity figure by 67%. This increase was based on the differences between tree-length and full-tree productivity in the Hinton, Alberta area(Ryan 1979). Productivity data for mechanical felling were obtained from the Canadian Pulp and Paper Association(1979, 1980). Tree-length figures are taken from the 1980 publication, whereas full-tree data was calculated by averaging the data from both years. The average was used because data varied so widely between publications. Table 22 outlines harvesting productivity.

B. Harvesting costs

As calculated in Table 23, manual harvesting costs totalled $15.41/m³. Mechanical harvesting costs are 25%

TABLE 22

PRODUCTIVITY OF HARVESTING METHODS

Method	Productivity	
	cunits/hr	m^3/hr
TL manual	2.00*	5.66
FT manual	2.97*	8.41
TL mechanical	0.99	2.80
FT mechanical	1.54	4.36

Note: TL--tree length;FT--full tree

*Assumed 3-man crew

TABLE 23

TREE LENGTH HARVESTING COSTS

Cost Centre	Costs ($\$/m^3$)	
	1977*	1980**
felling, limbing, skidding	4.81	7.21
skidroads, landings	0.37	0.54
loading	0.37	0.54
camp costs	0.67	0.97
overhead	2.14	3.21
road costs	2.03	2.94
TOTAL	10.39	15.41

*Source: Alberta Energy and Natural Resources. 1979. Energy and chemicals from wood. Energy and Natural Res. Rep. No. 90, Edmonton, Alta. p. 13.

**Source for price indexes: Statistics Canada. 1981. Construction price statistics. Min. of Supply and Services Can., Cat. 62-007, Vol. 8, No. 3, Ottawa, Ont. p. 43.; Statistics Canada, 1981. Estimates of labour income. Min. of Supply and Services Can., Cat. 72-005, Vol. 35, No. 1, Ottawa, Ont. p. 34.

higher or $19.26/m³. The units of the harvesting variables in the matrix are in hours, therefore these costs must be expressed in $/hr to satisfy equation units. The productivity figures used for the conversion are:

tree-length manual:	$\$15.41/m^3$	X	$5.66\ m^3/hr$	=	$87.22/hr,
tree-length mechanical:	$\$19.26/m^3$	X	$2.80\ m^3/hr$	=	$53.94/hr,
full-tree manual:	$\$15.41/m^3$	X	$8.41\ m^3/hr$	=	$129.60/hr,
full-tree mechanical:	$\$19.26/m^3$	X	$4.36\ m^3/hr$	=	$83.98/hr.

APPENDIX 2. TREE SIZE CALCULATIONS

The content of this appendix discribes the development of aspen size classes, the distribution of size classes on the harvest areas and the calculations describing the harvesting of individual size classes.

A. Aspen size classes

Bailey and Dobie(1977) recorded the size class distribution of an aspen stand in the Slave Lake region. The stand contained 72% trembling aspen and 28% balsam poplar. The weighted tree size distribution in Table 24 was developed from this information.

B. Distribution of size classes

Alberta Forest Service(1971) information provides stand volume data for trees smaller than 25.4 cm DBH and trees larger than 25.4 cm DBH. As was noted in Chapter 4, an assumption is made that only the 25.4 cm and greater portion will be delivered to the mills. This portion of the volume is assumed to include tree sizes down to 23 cm DBH. Multiplying the weighted averages from Table 24 by the percentage volumes of 25.4 cm and greater trees on each area gives the percentage of tree sizes available from the harvest areas as seen in Table 25.

C. Harvesting individual size classes

TABLE 24

WEIGHTED AVERAGES OF TREE SIZE CLASSES

DBH Class (cm)	Trembling Aspen (%)	Balsam Poplar (%)	Weighted Average (%)
23	16.0	12.0	14.9
30	41.0	29.0	37.6
38	24.0	30.0	25.7
46	19.0	29.0	21.8

TABLE 25

PERCENT DISTRIBUTION OF TREE SIZE CLASSES ON THE HARVEST AREAS

Harvest Area	Volume of trees 23+ cm (%)	DBH Class (cm)			
		23	30	38	46
1	53	7.9	19.9	13.6	11.6
2	59	8.8	22.2	15.2	12.9
3	57	8.5	21.2	14.6	12.4
4	62	9.2	23.3	15.9	13.5
5	66	9.8	24.8	17.0	14.4

Figure 3 illustrates the flow of the tree volumes through the felling portion of the matrix. The letters A and B are coefficients in the felling column and indicate the productivity(m^3/hr) for the different felling methods. The model assumes clearcutting on all areas but only a percentage of the volume felled will be hauled to the mills. These portions by size class are found in Table 25. The B coefficient is found by multiplying the A productivity coefficient by the portion assigned for an individual size class. For example, the productivity of tree length manual felling is 5.66 m^3/hr. On harvest area 1, 7.9% of the harvested trees will be of the 23 cm class. The B coefficent entered into the matrix for tree-length, manual felling on area 1 would be,

$$5.66\ m^3/hr \times 7.9\% = 0.448\ m^3/hr.$$

The other B coefficients were calculated in a similar manner.

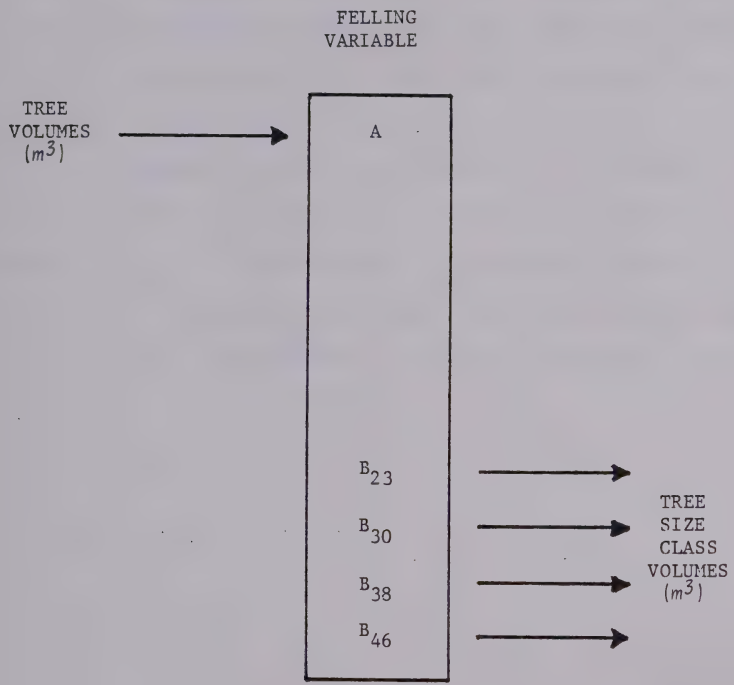

Figure 3. Flow of tree volumes through felling variables

APPENDIX 3. HAULING COST CALCULATIONS

McDougall(1978) reported a 1977 hauling cost in the Slave Lake area of \$0.07 per cord(cd) per running mile. By utilizing an average of both diesel fuel and wages and salaries price indexes[8], this figure was increased 66% to \$0.12/cd per running mile. The haul to Slave Lake is an average 145 km(90 mi) return. Hauling cost is:

$$\$0.12/\text{cd/mi} \times 90 \text{ mi} \times 0.2759 \text{ cd/m}^3 = \$2.98/\text{m}^3.$$

Unloading costs are assumed to be the same as loading costs(see Table 23) which amounts to \$0.54/m³. Therefore, the total cost for tree-length hauling and unloading comes to \$3.52/m³. Full-tree hauling costs are assumed to be 10% higher, thus totalling \$3.87/m³.

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[8] Statistics Canada. 1981. Industry price indexes. Minister of Supply and Services Canada, Cat. 62-011, Vol. 7, No.5, Ottawa, Ont. p. 57. and, Statistics Canada. 1981. Estimates of labour income. Minister of Supply and Services Canada, Cat. 72-005, Vol. 35, No. 1, Ottawa, Ont. p. 34.

APPENDIX 4. SAWMILL CONVERSION CALCULATIONS

This appendix includes a discussion of trees to sawlogs and sawmill conversion.

A. Conversion of trees to sawlogs

The amount of tree volume arriving at the sawmills must be adjusted to account for bark, branches and top and bucking to proper lengths. Keays(1971) determined the percentage of bark and branches and tops for different size classes of trembling aspen(Table 26). Tree-length volumes removed only the bark component, while percentages for bark, branches and tops were removed from full-tree volumes.

Log volumes as a percentage of tree volume for trembling aspen and balsam poplar in Alberta were documented by Bailey and Dobie(1977). These percentages were weighted according to the 80/20 assumed mix of trembling aspen to balsam poplar, then applied to the volume of the boles calculated in Table 26. Table 27 shows these calculations.

B. Stud and dimension sawmills conversion factors

Because the stud and dimension sawmills are essentially the same mill, lumber recovery is assumed to be the same for each. Lumber recovery factors(LRF) for both trembling aspen and balsam poplar were taken from the Bailey and Dobie(1977). The conversion of these factors into a percentage of lumber recovered and weighting to account for

TABLE 26

PERCENT VOLUME OF TREES FOR SAWLOGS

	Size Class (cm)			
	23	30	38	46
Bark	0.08	0.08	0.08	0.08
Branches and Top	0.06	0.05	0.04	0.03
Tree Length Bole	0.92	0.92	0.92	0.92
Full Tree Bole	0.86	0.87	0.88	0.89

TABLE 27

WEIGHTED SAWLOG VOLUMES AS PERCENT OF TREE VOLUMES

Size Class	Log Volumes TA (%)	Log Volumes BP (%)	Weighted Average (%)	Sawlog Volume, Tree Length (%)	Sawlog Volume, Full Tree (%)
23	81.0	81.0	81.4	0.749	0.700
30	87.0	83.0	86.5	0.796	0.752
38	86.0	81.0	85.0	0.782	0.748
46	89.0	84.5	88.1	0.810	0.784

Note: TA--trembling aspen; BP--balsam poplar.

stand mix is shown in Table 28.

The scrag-chipping edger mill system produces 100 tons of dry chips per day(Boywer 1974). This figure is converted to the proper units for matrix equations as follows:

100 tons/day X 909.1 kg/ton X 2.7 m^3 SWE /1.000 kg

= 245 m^3 chips/day.

Then,

245 m^3 chips/day X 0.00592 days/m^3 lumber

= 1.45 m^3 chips/m^3 lumber.

SWE is the solid wood equivalent of 1000 kg of trembling aspen wood(Dobie and Wright 1979).

The grades of lumber produced from aspen were evaluated by Bailey and Dobie(1977). These data were used to develop a weighted product mix of boards, studs and dimension lumber. The study showed that 8% of the lumber sawn became one-inch boards, with the remainder ending up as two-inch stock. Tables 29, 30 and 31 show the product calculations for boards, studs and dimension lumber respectively.

C. Twin and board sawmills conversion factors

The twin band system described by Leech and Gillies(1972) and the scrag mill used by Boywer(1974) manufactured factory lumber in the model. The twin system had a lumber recovery of 45.8% or a LRF of 5.5. Bailey(1973) found that straight aspen logs could achieve a LRF of 6.7 for one-inch factory lumber. This high LRF was attained because the study used large, straight logs. Bailey and

TABLE 28

LUMBER RECOVERY FOR STUD AND DIMENSION SAWMILLS

Size Class	LRF TA	Lumber Recovered TA (%)	LRF BP	Lumber Recovered BP (%)	Weighted Lumber Recovery (%)
23	5.90	49.0	5.80	48.0	48.8
30	7.00	58.0	6.30	52.0	56.8
38	7.30	61.0	6.70	56.0	60.0
46	7.60	63.0	7.40	61.0	62.6

Note: TA--trembling aspen; BP--balsam poplar.

TABLE 29

PRODUCT MIX FOR BOARDS

Grade	Volume of TA (fbm)	Percent of TA Total	Volume of BP (fbm)	Percent of BP Total	Weighted Average (%)	Percent of Total Production
select	1,273	42.0	836	40.0	41.6	0.033
construction	458	15.0	523	25.0	17.0	0.014
standard	742	25.0	474	23.0	24.6	0.020
utility	510	17.0	244	12.0	16.0	0.013
economy	32	1.0	8	...	0.8	0.001
TOTAL	3,016	100.0	2,084	100.0	100.0	...

Note: TA--trembling aspen; BP--balsam poplar.

TABLE 30

PRODUCT MIX FOR STUDS

Grade	Volume of TA (fbm)	Percent of TA Total	Volume of BP (fbm)	Percent of BP Total	Weighted Average (%)	Percent of Total Production
stud	29,787	87.0	22,550	85.0	86.6	0.797
economy stud	4,364	13.0	3,975	15.0	13.4	0.123
TOTAL	34,151	100.0	26,525	100.0	100.0	...

TABLE 31

PRODUCT MIX FOR DIMENSION LUMBER

Grade	Volume of TA (fbm)	Percent of TA Total	Volume of BP (fbm)	Percent of BP Total	Weighted Average (%)	Percent of Total Production
construction	17,351	50.0	11,216	42.0	41.6	0.445
standard	4,736	14.0	6,031	23.0	15.8	0.145
utility	8,001	23.0	5,302	20.0	22.4	0.206
economy	4,364	13.0	3,975	15.0	13.4	0.123
TOTAL	34,151	100.0	26,525	100.0	100.0	...

Note: TA--trembling aspen; BP--balsam poplar.

Dobie(1977) showed that smaller trees have a significantly lower LRF. Both Boywer (1974) and Bailey(1973) showed recovery for factory lumber to be lower than that of construction lumber. A LRF of 5.7(47.5%) is employed for the scrag mill to account for crooked, sweepy and smaller logs. Data could not be found on lumber recovery of factory lumber for different tree sizes. Therefore all size classes used the same average recovery.

Chip production from the twin band mill equalled 0.70 odt/Mfbm. This figure converts to 0.728 m^3 chips/m^3 of lumber produced using the technique outlined in stud and dimension chip conversion. Likewise the scrag mill produces 92 odt/day or 1.45 m^3 chips/m^3 of lumber. The chipping edger in the scrag system significantly increases the amount of chips produced by a mill.

Leech and Gillies(1972) study provided product mix data for both mills. The mixes are seen in Table 32.

TABLE 32

PRODUCT MIX OF FACTORY LUMBER

Grade	Twin Mill (%)	Board Mill (%)
#1&BTR	17	20
#2A	24	25
#2B	25	25
#3	34	30

APPENDIX 5. PULP CONVERSION CALCULATIONS

This appendix gives a detailed explaination of the conversion of roundwood to chips and the conversion of chips to pulp. The amount of chips available from roundwood is first considered. Woodbridge, *et.al.*(1981) noted that 85% of the usable bole of an aspen tree can be made into chips. This figure applied to the bole data shown in Table 26 gives the amount of chips available for pulp or particleboard from roundwood.

The second area of consideration is the conversion of chips to pulp. Pulp yield from aspen is calculated as follows: the pulp mill has a yearly solid wood requirement of 425,000 m^3, only half of which is aspen(i.e. 212,500 m^3). Eighty-five percent of the aspen wood brought to the mill is usable. The amount of aspen roundwood needed is:

$$212{,}500\ m^3/0.85 = 250{,}000\ m^3.$$

The mill's yearly production is 157,500 admt. The amount of aspen/admt is:

$$250{,}000\ m^3/157{,}500\ admt = 1.59\ m^3/admt.$$

Only 50% of aspen chips are usable in chemi-mechanical pulp, so

$$1.59\ m^3/0.50 = 3.18\ m^3/admt \text{ or } 0.1345\ admt/m^3$$

Spruce chips are also needed in the pulping process. The amount of spruce necessary for a single air-dry metric ton is 0.468 BDU.

Woodbridge, *et.al.*(1981) listed the operating cost of one air-dry metric ton of pulp as \$215.00. This figure includes \$44.50/ admt for harvesting. Because the model takes harvesting costs into account, the operating cost of the pulp mill was reduced to \$170.50/admt.

APPENDIX 6. WAFERBOARD CONVERSION AND COSTS

Conversion and cost figures for waferboard production were obtained from Columbia Engineering International Ltd. (1981). Waferboard requires 0.763 odt of wood/Msf, 3/8-inch basis. The metric conversion of this figure is 2.116 m^3 of wood input per cubic metre of waferboard, or 0.473 m^3 produced/m^3 input. The 0.473 m^3/m^3 can be used to convert the percentage of bole available into waferboard(Table 33).

The capital cost of the waferboard mill used in the model is $37,546,665. The information available did not differentiate depreciable items, but used 10 year, straight-line depreciation in the analysis. Manufacturing costs are shown in Table 34.

TABLE 33

ROUNDWOOD TO WAFERBOARD CONVERSION

Tree Type	Size Class (cm)	Percent Bole	Waferboard Conversion (m^3/m^3)
tree length	all	92	0.435
full tree	23	86	0.407
full tree	30	87	0.412
full tree	38	88	0.416
full tree	46	89	0.421

TABLE 34

MANUFACTURING COSTS OF WAFERBOARD

Item	Cost (\$/Msf, 3/8-inch basis)
resins and wax	24.28
power	8.00
fuel	3.00
labour	14.70
supplies	8.75
administration	5.50
insurance and local taxes	3.25
TOTAL	67.75
TOTAL(\$/m^3)	76.55

APPENDIX 7. PLYWOOD PRODUCTION CALCULATIONS

This appendix is composed of two parts. The first describes the method of deriving log sizes from tree size data. The second part uses Boywer's(1974) method of determining veneer production from different log sizes.

A. Log sizes

Roundwood to plywood conversion factors can be calculated using data from the literature(Boywer 1974). These factors are based upon the top diameter of 2.54 m(100 in) logs. The tree volumes used in the model must be converted into log volumes to utilize the conversion factors. Please refer to Table 35 as the logic of the calculations to determine log sizes is explained.[9]

The first step in calculating the logs in a tree is to determine tree height. Tree heights to merchantable tops were determined by utilizing rough height information from Bailey(1973). Next, the number of logs in a tree of a given diameter was evaluated. Both Bailey(1973) and Bailey and Dobie (1977) gave some data on the number of 8.33 ft logs that could be expected in a given sized trees. The usable and cull portions of the tree length was then calculated. The length of usable tree-length was determined by multiplying the number of logs in the tree by 8.33 ft. Cull lengths were found by subtracting the usable portion of the

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[9] All calculations in this section were done in English units because the literature used these units.

TABLE 35

CALCULATING THE DIAMETER OF PLYWOOD LOGS

Tree Size Class (cm)	DBH (in)	Height (ft)	Logs per Tree	Usable Log Length (ft)	Cull Length (ft)	Butt Dia. (in)	First Log Bottom Dia. (in)
23	9	38	3.50	29.2	8.8	9.5	8.8
	10	41	4.00	33.3	7.7	10.5	9.9
	11	41	4.50	37.5	3.5	11.5	11.2
30	12	50	4.50	37.5	12.5	12.5	11.6
	13	53	5.00	41.6	11.4	13.5	12.6
	14	56	5.50	45.8	10.2	14.5	13.7
38	15	58	5.50	45.8	12.2	15.5	14.6
	16	58	6.00	50.0	8.0	16.5	15.9
	17	58	6.25	52.0	6.0	17.5	17.0
46	18	62	6.25	52.0	10.0	18.5	17.8
	19	62	6.50	54.2	7.8	19.5	18.9
	20	62	6.75	56.2	5.8	20.5	20.1

tree from the total tree length.

Diameters along the length of the tree could be calculated using Leech and Gillies(1972) reported aspen taper of 0.15 in/ft. Butt diameter was calculated by multiplying the taper by 3.5 ft and subtracting the result from the DBH. The calculations to derive the diameters of the logs rely on the assumption that the cull portions of the tree-length are evenly divided between top and bottom. In other words, crook, sweep and rot were assumed to be either at the top or bottom of the tree. The length of cull in the butt portion of the tree is one-half the total cull length. The butt-cull length multiplied by the taper gives the amount of diameter taper over the butt-cull length. This figure was then subtracted from the butt diameter to give the bottom diameter of the first log. The top diameter of the first usable log was determined by subtracting 1.25 in(8.33 ft X 0.15 in/ft) from the bottom diameter. Similarly, log top diameters were calculated by 8.33 ft increments until the diameter was 8 in or smaller.

Two factors limit the utilization of every possible log in the tree. The first is that logs with a top diameter of 8 in or less cannot be processed by the mill at a profit. The other limitation is the number of logs that are possible in a tree. A tree could have nine logs of 8 in and greater top diameter but have only 7 possible logs in the tree. In the smaller DBH size classes, the opposite is true. There are three logs possible per tree but only one of them has a top

diameter of 8 in or greater. The figures in Table 36 were tablulated using these limitation factors. The percentage of logs in the tree size classes was calculated by dividing the total number of logs in a particular top diameter class by the total number of logs possible in the tree size class.

An example of one tree may be helpful. A tree of 11 in DBH was assumed to have a merchantable length of 41 ft and contain 4.5 logs. The total length of usable logs is:

$$8.33 \text{ ft/log} \times 4.5 \text{ logs} = 37.5 \text{ ft}.$$

This leaves 3.5 ft of unusable material. The butt diameter is:

$$11 \text{ in} = (3.5 \text{ ft} \times 0.15 \text{ in}) = 11.5 \text{ in}.$$

The bottom diameter of the first usable log is:

$$11.5 \text{ in} - (3.5 \text{ ft}/2 \times 0.15 \text{ in/ft}) = 11.24 \text{ in}.$$

The top diameter of the first log is:

$$11.24 \text{ in} - 1.25 \text{ in} = 9.99 \text{ in}.$$

Likewise, the second log's top diameter is 8.74 in and the third's 7.5 in. Even though this DBH size can have 4.5 logs, only 2 can meet the top diameter limitation of 8 in. In the whole 9 in(23 cm) DBH size class, only 25% of all logs possible can be used in the plywood mill.

Cull material can be chipped and utilized for pulp or particleboard. Alberta Energy and Natural Resources(1979) gave a 1977 chipping price of $13/odt. The 1980 price is

TABLE 36

CONVERSION OF TREE VOLUMES TO PLYWOOD LOG VOLUMES

Tree Size Class (cm)	Logs in Trees	Log Size Classes(%) 20 cm	28 cm	36 cm	43 cm	cull
23	12	0.250	...	...	...	0.750
30	16	0.375	0.188	...	...	0.438
38	18	0.444	0.333	0.667	...	0.057
46	20	0.100	0.400	0.350	0.150	...

inflated to \$19.50/odt[10] or 7.94 m^3. A conversion factor of 2.945 m^3/BDU was used in the matrix to adjust chip production to proper units (Dobie and Wright 1979).

B. Veneer production

Boywer's(1974) explanation of veneer production is used in Table 37. Log volumes for various top diameter classes are calculated and a percentage of this volume is removed to account for the five-inch core. The amount of 1/8-inch veneer is calculated, then reduced by 39.59% to account for drying and cull. Finally, the cubic feet of veneer is determined and the percentage of veneer to total log volume is calculated.

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[10]Source: Statistics Canada. 1981. Estimates of labour income. Minister of Supply and Services Can., Cat. 62-011, Ottawa, Ont. p. 34.

TABLE 37

VENEER PRODUCTION FROM PLYWOOD BOLTS

Log Top Dia. (in)	Log Vol. (ft^3)	Core Vol. (ft^3)	Core to Log Vol. (%)	Core Av. Vol. (%)	1/8-in Veneer (lineal ft)	1/8-in Veneer (sf)	Drying and Cull Ded.	Oven Dry Veneer (ft^3)	Veneer to Log Vol. (ft^3)	Veneer Av. Vol. (%)
8	3.30	1.09	33	...	25.7	206	125	1.3	39	...
9	4.14	1.09	26	27	35.5	284	172	1.8	43	43
10	5.27	1.09	21	...	48.6	389	235	2.4	46	...
11	6.26	1.09	17	...	60.1	481	291	3.0	48	...
12	7.37	1.09	15	15	73.0	584	353	3.6	40	49
13	8.72	1.09	13	...	83.5	688	416	4.2	49	...
14	10.12	1.09	11	...	105.0	840	508	5.2	52	...
15	11.62	1.09	9	9	122.4	879	592	6.1	53	53
16	13.22	1.09	8	...	141.0	1128	683	7.0	53	...
17	14.92	1.09	7	...	160.8	1280	775	8.0	54	...
18	16.72	1.09	6	6	181.9	1456	881	9.1	55	55
19	18.62	1.09	6	...	203.8	1630	986	10.3	55	...

Note: The drying and cull deduction is 39.5% of possible veneer.

APPENDIX 8. COSTS FOR LUMBER, PARTICLEBOARD AND PLYWOOD PRODUCTION

The capital and manufacturing costs for the sawmills, the particleboard mill and the plywood mill are described in this appendix. Boywer(1977) supplied the cost data for all mills with the exception of the twin band sawmill. The costs for the twin came from Leech and Gillies(1972). The data given in these publications were adjusted to 1980 prices using Statistics Canada price index information. Buildings and equipment are depreciated over 8 years using the straight-line method. The sawmill sites require 23 hectares of land and the sites for the particleboard mill and plywood mill each need 16 hectares. Land is available for $4942/ha (Holtby 1981). An advertising and property tax cost is included for every mill in the model. This cost is based upon the amount of goods sold, and is deducted from the profit at that time. Table 38 outlines sawmill costs and Table 39 shows particleboard and plywood costs.

TABLE 38

COST OF LUMBER PRODUCTION

Item	Index	Scrag System ($ X 1000)		Twin System ($ X 1000)	
		1974	1980	1972	1980
Capital Costs					
building and engineering	1	167	304	360	833
equipment	2	865	1508	790	1751
land	...	36	100	...	100
TOTAL	...	1068	1912	1150	2684
Depreciation/year	...	...	226	...	323
Manufacturing Costs					
telephone	3	6	8	...	...
general supplies	4	20	38	...	...
supplies and fuel	5	...	...	106	395
heat	6	1	3	...	...
electricity	7	25	55	...	...
office supplies	8	3	5	...	...
insurance	9	13	25	...	202
fuel for trans.	10	2	6	...	...
wages and salaries	11	207	509	303	1066
TOTAL	...	277	649	409	1663

Note: Index gives the reference number at end of appendix.

TABLE 39

COST OF PARTICLEBOARD AND PLYWOOD PRODUCTION

Item	Index	Particleboard Mill ($ X 1000)		Plywood Mill ($ X 1000)	
		1974	1980	1974	1980
Capital Costs					
building and engineering	1	1077	1959	1149	2090
equipment	2	3528	6149	2019	3520
land	...	72	80	72	80
TOTAL	...	4677	8188	3240	5690
Depreciation/year	...	...	1014	...	701
Manufacturing Costs					
adhesives	12	1219	2036	234	391
packaging	13	57	96	23	39
telephone	3	12	15	12	15
general supplies	4	8	15	6	12
repair and mant.	14	130	153	60	106
heat and power	15	218	508	86	200
insurance	9	57	97	41	67
fuel for trans.	10	8	22	6	17
wages and salaries	11	939	2310	928	2286
TOTAL	...	2648	5252	1396	3133

Note: Index gives the reference number at end of appendix.

INDEX REFERENCE

Many indicies were used from Statistics Canada to update mill costs to a 1980 basis. For ease of reference, the index entries will refer to the following publications by source letter.

SOURCE

A Statistics Canada. 1978. Fixed capital flows and stocks, 1926-1978. Minister of Supply and Services Can., Cat. 13-568, Ottawa, Ont.

B Statistics Canada. 1981. Construction price statistics. Minister of Supply and Services Can., Cat. 62-007, Vol. 8, No. 3, Ottawa, Ont.

C Statistics Canada. 1981. Consumer price indexes. Minister of Supply and Services Can., Cat. 62-010, Vol. 7, No. 3, Ottawa, Ont.

D Statistics Canada. 1981. Estimates of labour income. Minister of Supply and Services Can., Cat. 72-005, Vol. 35, No. 1, Ottawa, Ont.

E Statistics Canada. 1981. Industry price indexes. Minister of Supply and Services Can., Cat. 62-011, Vol. 7, No. 5, Ottawa, Ont.

INDEX NO.	DESCRIPTION
1	An average of source A(wood, p. 248) and source B (industrial buildings, p. 28).
2	Sawmill and plywood equipment came from source E (sawmill machinery, p. 48). Particleboard equipment used source E(pulp and paper machinery and parts, p. 48).
3	Telephone cost index came from source C(telephone, p. 29).
4	All general supplies indices came from source E and averaged: bolts and nuts and headed or threaded

rods with or without nuts, p.45; carpenter mechanic hand tools, p. 45; lighting fixtures, p.51; electrical industrial equipment, p. 51; misc. electrical products, p. 52; indicating, recording and controlling instruments and accessories, p. 62.

5 The supplies and fuel index averaged all the items listed in index 4 plus the diesel fuel index(p. 57) of source E.

6 Heat was assumed to utilize natural gas which is indexed in source C, p. 29.

7 The cost of electricity was indexed in source E (Alberta-over 5000 kw, p. 67).

8 Office supplies were indexed using an average in source E of typewriter supplies(p. 63), pen and pencils manufactured(p. 63), pads and tablets(p. 40) and envelopes manufactured(p. 41).

9 Insurance was determined by calculating 1% of the sum of capital expenditures and estimated working capital.

10 Fuel was indexed using source E, diesel fuel(p. 57).

11 Wages and salaries utilized source C, labour income of Alberta manufacturing industries(p. 34).

12 Adhesives were indexed using source E, glues-all types(p. 62).

13 Packaging used source E, paperboard, container grades, liners, Kraft paper board(p. 38).

14 Repair and maintenance was calculated by taking 1% of the building and equipment cost and multiplying this figure by the number of shifts per day.

15 The heat and power index was calculated by averaging natural gas indexes(source C, p. 29) and electricity indexes(source E, p. 67).

APPENDIX 9. REFERENCE MATRIX

This appendix contains a listing of the reference matrix variables, a picture of the reference matrix and the reference matrix itself.

A. Listing of the matrix variables

1. ROWS

ZMAX --objective function($)
OPCAP --operating capital($)
ALLOWCUT--total annual allowable cut(m^3)
LIMHAR1 --limit of harvest area 1(ha)
LIMHAR2 --limit of harvest area 2(ha)
LIMHAR3 --limit of harvest area 3(ha)
LIMHAR4 --limit of harvest area 4(ha)
LIMHAR5 --limit of harvest area 5(ha)
TLAMT1 --tree length volume from harvest area 1(m^3)
TLAMT2 --tree length volume from harvest area 2(m^3)
TLAMT3 --tree length volume from harvest area 3(m^3)
TLAMT4 --tree length volume from harvest area 4(m^3)
TLAMT5 --tree length volume from harvest area 5(m^3)
FTAMT1 --full tree volume from harvest area 1(m^3)
FTAMT2 --full tree volume from harvest area 2(m^3)
FTAMT3 --full tree volume from harvest area 3(m^3)
FTAMT4 --full tree volume from harvest area 4(m^3)
FTAMT5 --full tree volume from harvest area 5(m^3)
TLSIZ9 --tree length 23 cm trees(m^3)
TLSIZ12 --tree length 30 cm trees(m^3)
TLSIZ15 --tree length 38 cm trees(m^3)
TLSIZ18 --tree length 46 cm trees(m^3)
FTSIZ9 --full tree 23 cm trees(m^3)
FTSIZ12 --full tree 30 cm trees(m^3)
FTSIZ15 --full tree 38 cm trees(m^3)
FTSIZ18 --full tree 46 cm trees(m^3)
BARK --bark component of trees(m^3)
BRAN-TOP--branch and top component of full trees(m^3)
CHIPS --chips(m^3)
LOGS9 --volume OF 23 cm boles(m^3)
LOGS12 --volume OF 30 cm boles(m^3)
LOGS15 --volume OF 38 cm boles(m^3)
LOGS18 --volume OF 46 cm boles(m^3)
LOG8 --volume OF 20 cm plywood bolts(m^3)
LOG11 --volume OF 28 cm plywood bolts(m^3)
LOG14 --volume OF 36 cm plywood bolts(m^3)

LOG17 --volume OF 43 cm plywood bolts(m^3)
STUDTRAN--stud transfer(m^3)
CAPSTUD --capital transfer for stud mill($)
LIMS&D --limit on stud and dimension sawmills(m^3)
DIMTRAN --dimension lumber transfer(m^3)
CAPDIM --capital transfer for dimension mill($)
TWINMILL--twin mill's production transfer(m^3)
CAPTWIN --capital transfer for twin mill($)
LIMTWIN --limit on twin mill production(m^3)
BOARDTRN--board mill's production transfer(m^3)
CAPBOARD--capital transfer for board mill($)
LIMBOARD--limit on board mill production(m^3)
PULPTRAN--pulp transfer(admt)
CAPPULP --capital transfer for pulp mill($)
LIMPULP --limit on pulp production(admt)
SPNEED --spruce transfer(m^3)
PBTRAN --particleboard transfer(m^3)
CAPPART --capital transfer for particleboard mill($)
LIMPB --limit on particleboard production(m^3)
WAFERCON--waferboard conversion(m^3)
WAFTRAN --waferboard transfer(m^3)
CAPWAFER--capital transfer for waferboard mill($)
LIMWAFER--limit on waferboard production(m^3)
PLYCON --plywood conversion(m^3)
CAPPLY --capital transfer for plywood mill($)
LIMPLY --limit on plywood production(m^3)
PLYTRIM --plywood trim produced(m^3)
LOGCHIP --plywood bolt trim volume(m^3)
AD&TAX --advertising and property tax transfer($)
PULPPROD--pulp production(admt)
PBPROD --particleboard production(m^3)
WAFERPRO--waferboard production(m^3)
PLYPROD --plywood production(m^3)
STSLETBD--select boards from stud mill(m^3)
STCONBD --construction boards from stud mill(m^3)
STSTDBD --standard boards from stud mill(m^3)
STUTILBD--utility boards from stud mill(m^3)
STECONBD--economy boards from stud mill(m^3)
DMSLETBD--select boards from dimension mill(m^3)
DMCONBD --construction boards from dimension mill(m^3)
DMSTDBD --standard boards from dimension mill(m^3)
DMUTILBD--utility boards from dimension mill(m^3)
DMECONBD--economy boards from dimension mill(m^3)
DMCONST --construction lumber from dimension mill(m^3)
DMSTAND --standard lumber from dimension mill(m^3)
DMUTIL --utility lumber from dimension mill(m^3)
DMECON --economy lumber from dimension mill(m^3)
TWINBD1 --#1 and better boards from twin mill(m^3)
TWINBD2A--#2A boards from twin mill(m^3)
TWINBD2B--#2B boards from twin mill(m^3)
TWINBD3 --#3 boards from twin mill(m^3)
BOARD1 --#1 and better boards from board mill(m^3)
BOARD2A --#2A boards from board mill(m^3)
BOARD2B --#2B boards from board mill(m^3)

BOARD3 --#3 boards from board mill(m^3)

2. COLUMNS

HARVEST1--tree length portion of harvest area 1(ha)
HARVEST2--tree length portion of harvest area 2(ha)
HARVEST3--tree length portion of harvest area 3(ha)
HARVEST4--tree length portion of harvest area 4(ha)
HARVEST5--tree length portion of harvest area 5(ha)
HARVES1A--full tree portion of harvest area 1(ha)
HARVES2A--full tree portion of harvest area 2(ha)
HARVES3A--full tree portion of harvest area 3(ha)
HARVES4A--full tree portion of harvest area 4(ha)
HARVES5A--full tree portion of harvest area 5(ha)
TL1AR1--tree length, manual harvesting of area 1(hr)
TL2AR1--tree length, mechanical harvesting of area 1(hr)
FT1AR1--full tree, manual harvesting of area 1(hr)
FT2AR1--full tree, mechanical harvesting of area 1(hr)
TL1AR2--tree length, manual harvesting of area 2(hr)
TL2AR2--tree length, mechanical harvesting of area 2(hr)
FT1AR2--full tree, manual harvesting of area 2(hr)
FT2AR2--full tree, mechanical harvesting of area 2(hr)
TL1AR3--tree length, manual harvesting of area 3(hr)
TL2AR3--tree length, mechanical harvesting of area 3(hr)
FT1AR3--full tree, manual harvesting of area 3(hr)
FT2AR3--full tree, mechanical harvesting of area 3(hr)
TL1AR4--tree length, manual harvesting of area 4(hr)
TL2AR4--tree length, mechanical harvesting of area 4(hr)
FT1AR4--full tree, manual harvesting of area 4(hr)
FT2AR4--full tree, mechanical harvesting of area 4(hr)
TL1AR5--tree length, manual harvesting of area 5(hr)
TL2AR5--tree length, mechanical harvesting of area 5(hr)
FT1AR5--full tree, manual harvesting of area 5(hr)
FT2AR5--full tree, mechanical harvesting of area 5(hr)
HAULSAW1--hauling 23 cm tree length sawlogs(m^3)
HAULSAW2--hauling 30 cm tree length sawlogs(m^3)
HAULSAW3--hauling 38 cm tree length sawlogs(m^3)
HAULSAW4--hauling 46 cm tree length sawlogs(m^3)
HAULSAW5--hauling 23 cm full tree sawlogs(m^3)
HAULSAW6--hauling 30 cm full tree sawlogs(m^3)
HAULSAW7--hauling 38 cm full tree sawlogs(m^3)
HAULSAW8--hauling 46 cm full tree sawlogs(m^3)
HAULCHP1--hauling all tree lengths for chips(m^3)
HAULCHP2--hauling 23 cm full trees for chips(m^3)
HAULCHP3--hauling 30 cm full trees for chips(m^3)
HAULCHP4--hauling 38 cm full trees for chips(m^3)
HAULCHP5--hauling 46 cm full trees for chips(m^3)
HAULWAF1--hauling all tree lengths for wafers(m^3)
HAULWAF2--hauling 23 cm full trees for wafers(m^3)
HAULWAF3--hauling 30 cm full trees for wafers(m^3)
HAULWAF4--hauling 38 cm full trees for wafers(m^3)
HAULWAF5--hauling 46 cm full trees for wafers(m^3)
HAULPLY1--hauling 23 cm tree lengths for plywood bolts(m^3)
HAULPLY2--hauling 30 cm tree lengths for plywood bolts(m^3)

HAULPLY3--hauling 38 cm tree lengths for plywood bolts(m^3)
HAULPLY4--hauling 46 cm tree lengths for plywood bolts(m^3)
HAULPLY5--hauling 23 cm full trees for plywood bolts(m^3)
HAULPLY6--hauling 30 cm full trees for plywood bolts(m^3)
HAULPLY7--hauling 38 cm full trees for plywood bolts(m^3)
HAULPLY8--hauling 46 cm full trees for plywood bolts(m^3)
STUDMILL--stud sawmill production(m^3)
STUDCAP --stud sawmill depreciation and purchase(m^3)
DIMMILL --dimension sawmill production(m^3)
DIMCAP --dimension sawmill depreciation and purchase(m^3)
TWINMILL--twin sawmill production(m^3)
TWINCAP --twin sawmill depreciation and purchase(m^3)
BOARDMIL--board sawmill production(m^3)
BOARDCAP--board sawmill depreciation and purchase(m^3)
PULPMILL--pulp mill production(admt)
PULPCAP --pulp mill depreciation and purchase(admt)
SPRUCE --spurce needed for pulp(BDU)
PARTMILL--particleboard mill production(m^3)
PARTCAP --particleboard mill depreciation and purchase(m^3)
WAFERMIL--waferboard mill production(m^3)
WAFERCAP--waferboard mill depreciation and purchase(m^3)
PLYMILL1--20 cm plywood mill production(m^3)
PLYMILL2--28 cm plywood mill production(m^3)
PLYMILL3--36 cm plywood mill production(m^3)
PLYMILL4--43 cm plywood mill production(m^3)
PLYCAP --plywood mill depreciaton and purchase(m^3)
CHIPLOG --plywood tree residue that is chipped(m^3)
TAX&AD --property tax and advertising cost deduction(m^3)
AVALCHIP--selling chips(m^3)
SLECTBD --select boards from stud mill(Mfbm)
CONSTBD --construction boards from stud mill(Mfbm)
STANDBD --standard boards from stud mill(Mfbm)
UTILBD --utility boards from stud mill(Mfbm)
ECONOBD --economy boards from stud mill(Mfbm)
SLECTBDD--select boards from dimension mill(Mfbm)
CONSTBDD--construction boards from dimension mill(Mfbm)
STANDBDD--standard boards from dimension mill(Mfbm)
UTILBDD --utility boards from dimension mill(Mfbm)
ECONOBDD--economy boards from dimension mill(Mfbm)
CONSTDIM--construction lumber from dimension mill(Mfbm)
STANDDIM--standard lumber from dimension mill(Mfbm)
UTILDIM --utility lumber from dimension mill(Mfbm)
ECONODIM--economy lumber from dimension mill(Mfbm)
STUD --studs from stud mill(Mfbm)
ECONOSTD--economy studs from stud mill(Mfbm)
BD#1BTR --#1 and better boards from board sawmill(Mfbm)
BD#2A --#2A boards from board sawmill(Mfbm)
BD#2B --#2B boards from board sawmill(Mfbm)
BD#3 --#3 boards from board sawmill(Mfbm)
BD#1BTRT--#1 and better boards from twin sawmill(Mfbm)
BD#2AT --#2A boards from twin sawmill(Mfbm)
BD#2BT --#2B boards from twin sawmill(Mfbm)
BD#3T --#3 boards from twin sawmill(Mfbm)
PULP --pulp(admt)

PB3/4 --19 mm sheets of particleboard(m³)
PB5/8 --16 mm sheets of particleboard(m³)
PB1/2 --13 mm sheets of particleboard(m³)
PB3/8 --9 mm sheets of particleboard(m³)
WAF1/4 --6 mm sheets of waferboard(m³)
WAF5/16 --8 mm sheets of waferboard(m³)
WAF3/8 --9 mm sheets of waferboard(m³)
WAF7/16 --11 mm sheets of waferboard(m³)
WAF5/8TG--16 mm sheets of waferboard(m³)
PLY1/4 --6 mm sheets of plywood(m³)
PLY1/2 --13 mm sheets of plywood(m³)
PLY3/4 --19 mm sheets of plywood(m³)
TRIMROND--plywood trim and rounding residue(m³)
HOGFUEL --hogfuel(m³)
MONEYSTD--capital cost of stud sawmill($)
MONEYDIM--capital cost of dimension sawmill($)
MONEYTWN--capital cost of twin sawmill($)
MONEYBOR--capital cost of board sawmill($)
MONEYPLP--capital cost of pulp mill($)
MONEYPRT--capital cost of particlebard mill($)
MONEYWAF--capital cost of waferboard mill($)
MONEYPLY--capital cost of particleboard mill($)
OPERAT$$--operating costs($)

PICTURE OF MATRIX

		HARVEST1	HARVEST2	HARVEST3	HARVEST4	HARVEST5	HARVES1A	HARVES2A	HARVES3A	HARVES4A	HARVES5A	TL1AR1	TL2AR1	FT1AR1	FT2AR1	TL1AR2	TL2AR2	FT1AR2	FT2AR2	TL1AR3	TL2AR3	FT1AR3	FT2AR3	TL1AR4	TL2AR4	FT1AR4	FT2AR4	TL1AR5	TL2AR5	FT1AR5	FT2AR5	HAULSAW1	HAULSAW2	HAULSAW3	HAULSAW4	HAULSAW5	HAULSAW6	HAULSAW7	HAULSAW8	HAULCHP1	HAULCHP2	HAULCHP3	HAULCHP4	HAULCHP5	HAULWAF1	HAULWAF2	HAULWAF3	HAULWAF4	HAULWAF5	HAULPLY1	HAULPLY2	HAULPLY3	HAULPLY4	HAULPLY5	HAULPLY6	HAULPLY7
ZMAX	N	-B	-B	-B	-B	-B	-B	-B	-B	-B	-B	-B	-B	-C	-B	-B	-B	-C	-B	-B	-B	-C	-B	-B	-B	-C	-B	-B	-B	-C	-B	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A	-A
OPCAP	L	B	B	B	B	B	B	B	B	B	B	B	B	C	B	B	B	C	B	B	B	C	B	B	B	C	B	B	B	C	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
ALLOWCUT	L	B	B	C	C	C	B	B	C	C	C																																													
LIMHAR1	L	1					1																																																	
LIMHAR2	L		1					1																																																
LIMHAR3	L			1					1																																															
LIMHAR4	L				1					1																																														
LIMHAR5	L					1					1																																													
TLAMT1	L	-B										A	A																																											
TLAMT2	L		-B													A	A																																							
TLAMT3	L			-C																A	A																																			
TLAMT4	L				-C																			A	A																															
TLAMT5	L					-C																						A	A																											
FTAMT1	L						-B							A	A																																									
FTAMT2	L							-C										A	A																																					
FTAMT3	L								-C													A	A																																	
FTAMT4	L									-C																A	A																													
FTAMT5	L										-C																			A	A																									
TLSIZ9	L											-T	-T			-T	-T			-T	-T			-T	-T			-T	-T			1								1					1					1						
TLSIZ12	L											-A	-T			-A	-T			-A	-T			-A	-T			-A	-T				1							1					1						1					
TLSIZ15	L											-T	-T			-T	-T			-T	-T			-T	-T			-T	-T					1						1					1							1				
TLSIZ18	L											-T	-T			-T	-T			-T	-T			-T	-T			-T	-T						1					1					1								1			
FTSIZ9	L													-T	-T			-T	-T			-T	-T			-T	-T			-T	-T					1					1					1								1		
FTSIZ12	L													-A	-T			-A	-T			-A	-T			-A	-A			-A	-A						1					1					1								1	
FTSIZ15	L													-A	-T			-A	-T			-A	-T			-A	-T			-A	-T							1					1					1								1
FTSIZ18	L													-T	-T			-A	-T			-A	-T			-A	-T			-A	-T								1					1					1							
BARK	L																															-U	-U	-U	-U	-U	-U	-U	-U	-U	-U	-U	-U	-U						-U	-U	-U	-U	-U	-U	-U
BRAN-TOP	L																																			-U	-U	-U	-U		-U	-U	-U	-U										-U	-U	-U
CHIPS	L																																							-T	-T	-T	-T	-T												
LOGS8	L																															-T				-T																				
LOGS12	L																																-T				-T																			
LOGS15	L																																	-T				-T																		
LOGS18	L																																		-T				-T																	
LOG8	L																																																	-T	-T	-T	-U	-T	-T	-T
LOG11	L																																																		-T	-T	-T		-T	-T
LOG14	L																																																			-T	-T			-T
LOG17	L																																																				-T			
STUDTRAN	L																																																							
CAPSTUD	L																																																							
LIMS&D	L																																																							
DIMTRAN	L																																																							
CAPDIM	L																																																							
TWINTRAN	L																																																							
CAPTWIN	L																																																							
LIMTWIN	L																																																							
BOARDTRN	L																																																							
CAPBOARD	L																																																							
LIMBOARD	L																																																							
PULPTRAN	L																																																							
CAPPULP	L																																																							
LIMPULP	L																																																							
SPNEED	L																																																							
PBTRAN	L																																																							
CAPPART	L																																																							
LIMPB	L																																																							
WAFERCON	L																																												-T	-T	-T	-T	-T							
WAFTRAN	L																																																							
CAPWAFER	L																																																							
LIMWAFER	L																																																							
PLYCON	L																																																							
CAPPLY	L																																																							
LIMPLY	L																																																							
PLYTRIM	L																																																							
LOGCHIP	L																																																	-T	-T	-U		-T	-T	-U
AD&TAX	L																																																							
PULPPROD	L																																																							
PBPROD	L																																																							
WAFERPRO	L																																																							
PLYPROD	L																																																							
STSLETBD	L																																																							
STCONBD	L																																																							
STSTDBD	L																																																							
STUTILBD	L																																																							
STECONBD	L																																																							
STSTUD	L																																																							
STECON	L																																																							
DMSLETBD	L																																																							
DMCONBD	L																																																							
DMSTDBD	L																																																							
DMUTILBD	L																																																							
DMECONBD	L																																																							
DMCONST	L																																																							
DMSTAND	L																																																							
DMUTIL	L																																																							
DMECON	L																																																							
TWINBD1	L																																																							
TWINBD2A	L																																																							
TWINBD2B	L																																																							
TWINBD3	L																																																							
BOARD1	L																																																							
BOARD2A	L																																																							
BOARD2B	L																																																							
BOARD3	L																																																							

		HAULPLY8	STUDMILL	STUDCAP	DIMMILL	DIMCAP	TWINMILL	TWINCAP	BOARDMIL	BOARDCAP	PULPMILL	PULPCAP	SPRUCE	PARTMILL	PARTCAP	WAFERMIL	WAFERCAP	PLYMILL1	PLYMILL2	PLYMILL3	PLYMILL4	PLYCAP	CHIPLOG	TAX&AD	AVALCHIP	SLECTBD	CONSTBD	STANDBD	UTILBD	ECONOBD	SLECTBDD	CONSTBDD	STANDBDD	UTILBDD	ECONOBDD	CONSTDIM	STANDIM	UTILDIM	ECONODIM	STUD	ECONOSTD	BD#1BTR	BD#2A	BD#2B	BD#3	BD#1BTRT	BD#2AT	BD#2BT	BD#3T	PULP	PB3/4	PB5/8	PB1/2	PB3/8	WAF1/4	WAF5/16
ZMAX	N	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-B	-B	-B	-B	-B	-B	-B	-B	-B	-B	-B	-A	-U	X	C	C	C	C	B	C	C	C	C	B	C	C	C	B	C	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
OPCAP	L	A	B	A	B	A	B	A	B	A	B	B	B	B	B	B	B	B	B	B	B	B	A	U																																
ALLOWCUT	L																																																							
LIMHAR1	L																																																							
LIMHAR2	L																																																							
LIMHAR3	L																																																							
LIMHAR4	L																																																							
LIMHAR5	L																																																							
TLAMT1	L																																																							
TLAMT2	L																																																							
TLAMT3	L																																																							
TLAMT4	L																																																							
TLAMT5	L																																																							
FTAMT1	L																																																							
FTAMT2	L																																																							
FTAMT3	L																																																							
FTAMT4	L																																																							
FTAMT5	L																																																							
TLSIZ9	L																																																							
TLSIZ12	L																																																							
TLSIZ15	L																																																							
TLSIZ18	L																																																							
FTSIZ9	L																																																							
FTSIZ12	L																																																							
FTSIZ15	L																																																							
FTSIZ18	L	1																																																						
BARK	L	-U																																																						
BRAN-TOP	L	-U																																																						
CHIPS	L		-A		-A		-T		-A		1			1				-T	-T	-U	-U		-1		A																															
LOGS9	L		T		T		T		T																																															
LOGS12	L		T		T		T		T																																															
LOGS15	L		T		T		T		T																																															
LOGS18	L		T		T		T		T																																															
LOG8	L	-U																1																																						
LOG11	L	-T																	1																																					
LOG14	L	-T																		1																																				
LOG17	L	-T																			1																																			
STUDTRAN	L		-1	1																																																				
CAPSTUD	L			B																																																				
LIMS&D	L			1		1																																																		
DIMTRAN	L				-1	1																																																		
CAPDIM	L					B																																																		
TWINTRAN	L						-1	1																																																
CAPTWIN	L							B																																																
LIMTWIN	L							1																																																
BOARDTRN	L								-1	1																																														
CAPBOARD	L									B																																														
LIMBOARD	L									1																																														
PULPTRAN	L										-T	1																																												
CAPPULP	L											C																																												
LIMPULP	L											1																																												
SPNEED	L											1	-A																																											
PBTRAN	L													-T	1																																									
CAPPART	L														B																																									
LIMPB	L														1																																									
WAFERCON	L															1																																								
WAFTRAN	L															-1	1																																							
CAPWAFER	L																C																																							
LIMWAFER	L																1																																							
PLYCON	L																	-T	-T	-T	-T	1																																		
CAPPLY	L																					C																																		
LIMPLY	L																					1																																		
PLYTRIM	L																	-T	-T	-T	-T																																			
LOGCHIP	L																						1																																	
AD&TAX	L																							-1		C	C	C	C	B	C	C	C	C	B	C	C	C	B	C	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
PULPPROD	L											-1																																						1						
PBPROD	L														-1																																				1	1	1	1		
WAFERPRO	L																-1																																						1	1
PLYPROD	L																					-1																																		
STSLETBD	L			-U																						A																														
STCONBD	L			-U																							A																													
STSTDBD	L			-U																								A																												
STUTILBD	L			-U																									A																											
STECONBD	L			-V																										A																										
STSTUD	L			-T																																				A																
STECON	L			-T																																					A															
DMSLETBD	L					-U																									A																									
DMCONBD	L					-U																										A																								
DMSTDBD	L					-U																											A																							
DMUTILBD	L					-U																												A																						
DMECONBD	L					-V																													A																					
DMCONST	L					-T																														A																				
DMSTAND	L					-T																															A																			
DMUTIL	L					-T																																A																		
DMECON	L					-T																																	A																	
TWINBD1	L							-T																																						A										
TWINBD2A	L							-T																																							A									
TWINBD2B	L							-T																																								A								
TWINBD3	L							-T																																									A							
BOARD1	L									-T																																A														
BOARD2A	L									-T																																	A													
BOARD2B	L									-T																																		A												
BOARD3	L									-T																																			A											

		WAF3/8	WAF7/16	WAF5/8TG	PLY1/4	PLY1/2	PLY3/4	TRIMROND	HOGFUEL	MONEYSTD	MONEYDIM	MONEYTWN	MONEYBOR	MONEYPLP	MONEYPRT	MONEYWAF	MONEYPLY	OPERAT$$	RHS1
ZMAX	N	C	C	C	E	C	C	A	A	-T	-T	-T	-T	-T	-T	-T	-T	-T	
OPCAP	L																	-1	
ALLOWCUT	L																		G
LIMHAR1	L																		D
LIMHAR2	L																		D
LIMHAR3	L																		D
LIMHAR4	L																		D
LIMHAR5	L																		D
TLAMT1	L																		
TLAMT2	L																		
TLAMT3	L																		
TLAMT4	L																		
TLAMT5	L																		
FTAMT1	L																		
FTAMT2	L																		
FTAMT3	L																		
FTAMT4	L																		
FTAMT5	L																		
TLSIZ9	L																		
TLSIZ12	L																		
TLSIZ15	L																		
TLSIZ18	L																		
FTSIZ9	L																		
FTSIZ12	L																		
FTSIZ15	L																		
FTSIZ18	L																		
BARK	L								1										
BRAN-TOP	L								1										
CHIPS	L																		
LOGS9	L																		
LOGS12	L																		
LOGS15	L																		
LOGS18	L																		
LOG8	L																		
LOG11	L																		
LOG14	L																		
LOG17	L																		
STUDTRAN	L																		
CAPSTUD	L									-1									
LIMS&D	L																		E
DIMTRAN	L																		
CAPDIM	L										-1								
TWINTRAN	L																		
CAPTWIN	L											-1							
LIMTWIN	L																		E
BOARDTRN	L																		
CAPBOARD	L												-1						
LIMBOARD	L																		E
PULPTRAN	L																		
CAPPULP	L													-1					
LIMPULP	L																		F
SPNEED	L																		
PBTRAN	L																		
CAPPART	L														-1				
LIMPB	L																		F
WAFERCON	L																		
WAFTRAN	L																		
CAPWAFER	L															-1			
LIMWAFER	L																		F
PLYCON	L																		
CAPPLY	L																-1		
LIMPLY	L																		E
PLYTRIM	L							1											
LOGCHIP	L																		
AD&TAX	L	C	C	C	C	C	C												
PULPPROD	L																		
PBPROD	L																		
WAFERPRO	L	1	1	1															
PLYPROD	L				1	1	1												
STSLETBD	L																		
STCONBD	L																		
STSTDBD	L																		
STUTILBD	L																		
STECONBD	L																		
STSTUD	L																		
STECON	L																		
DMSLETBD	L																		
DMCONBD	L																		
DMSTDBD	L																		
DMUTILBD	L																		
DMECONBD	L																		
DMCONST	L																		
DMSTAND	L																		
DMUTIL	L																		
DMECON	L																		
TWINBD1	L																		
TWINBD2A	L																		
TWINBD2B	L																		
TWINBD3	L																		
BOARD1	L																		
BOARD2A	L																		
BOARD2B	L																		
BOARD3	L																		

SUMMARY OF MATRIX

SYMBOL	RANGE			COUNT (INCL.RHS)
Z	LESS	THAN	.000001	
Y	.000001	THRU	.000009	
X	.000010		.000099	1
W	.000100		.000999	
V	.001000		.009999	2
U	.010000		.099999	49
T	.100000		.999999	151
1	1.000000		1.000000	103
A	1.000001		10.000000	134
B	10.000001		100.000000	102
C	100.000001		1,000.000000	92
D	1,000.000001		10,000.000000	5
E	10,000.000001		100,000.000000	4
F	100,000.000001		1,000,000.000000	3
G	GREATER	THAN	1,000,000.000000	1

REFERENCE MATRIX

	HARVEST1	HARVEST2	HARVEST3	HARVEST4	HARVEST5	HARVES1A	HARVES2A	HARVES3A	1....1
ZMAX	34.50000-	44.65000-	61.10000-	75.67000-	84.13000-	34.50000-	44.65000-	61.10000-	ZMAX
OPCAP	34.50000	44.65000	61.10000	75.67000	84.13000	34.50000	44.65000	61.10000	OPCAP
ALLOWCUT	73.40000	95.00000	130.00000	161.10000	179.00000	73.40000	95.00000	130.00000	ALLOWCUT
LIMHAR1	1.00000	.	.	.	.	1.00000	.	.	LIMHAR1
LIMHAR2	.	1.00000	.	.	.	.	1.00000	.	LIMHAR2
LIMHAR3	.	.	1.00000	.	.	.	.	1.00000	LIMHAR3
LIMHAR4	.	.	.	1.00000	.	.	.	.	LIMHAR4
LIMHAR5	.	.	.	.	1.00000	.	.	.	LIMHAR5
TLAMT1	73.40000-	.	.	.	.	.	.	.	TLAMT1
TLAMT2	.	95.00000-	.	.	.	.	.	.	TLAMT2
TLAMT3	.	.	130.00000-	.	.	.	.	.	TLAMT3
TLAMT4	.	.	.	161.10000-	.	.	.	.	TLAMT4
TLAMT5	.	.	.	.	179.00000-	.	.	.	TLAMT5
FTAMT1	.	.	.	.	.	78.50000-	.	.	FTAMT1
FTAMT2	.	.	.	.	.	.	101.60000-	.	FTAMT2
FTAMT3	.	.	.	.	.	.	.	139.10000-	FTAMT3

	HARVES4A	HARVES5A	TL1AR1	TL2AR1	FT1AR1	FT2AR1	TL1AR2	TL2AR2	2....1
ZMAX	75.67000-	84.13000-	87.22000-	53.94000-	129.60000-	83.98000-	87.22000-	53.94000-	ZMAX
OPCAP	75.67000	84.13000	87.22000	53.94000	129.60000	83.98000	87.22000	53.94000	OPCAP
ALLOWCUT	161.10000	179.00000	.	.	.	.	.	.	ALLOWCUT
LIMHAR4	1.00000	.	.	.	.	.	.	.	LIMHAR4
LIMHAR5	.	1.00000	.	.	.	.	.	.	LIMHAR5
TLAMT1	.	.	5.66000	2.80000	.	.	.	.	TLAMT1
TLAMT2	.	.	.	.	.	.	5.66000	2.80000	TLAMT2
FTAMT1	.	.	.	.	8.41000	4.36000	.	.	FTAMT1
FTAMT4	172.30000-	.	.	.	.	.	.	.	FTAMT4
FTAMT5	.	191.50000-	.	.	.	.	.	.	FTAMT5
TLSIZ9	.	.	.48800-	.22100-	.	.	.49800-	.24600-	TLSIZ9
TLSIZ12	.	.	1.12800-	.55700-	.	.	1.25600-	.62200-	TLSIZ12
TLSIZ15	.	.	.77000-	.38100-	.	.	.86000-	.42600-	TLSIZ15
TLSIZ18	.	.	.65700-	.32500-	.	.	.73000-	.36100-	TLSIZ18
FTSIZ9	.	.	.	.	.66400-	.34400-	.	.	FTSIZ9
FTSIZ12	.	.	.	.	1.67400-	.86800-	.	.	FTSIZ12
FTSIZ15	.	.	.	.	1.14400-	.59300-	.	.	FTSIZ15
FTSIZ18	.	.	.	.	.97600-	.50600-	.	.	FTSIZ18

	FT1AR2	FT2AR2	TL1AR3	TL2AR3	FT1AR3	FT2AR3	TL1AR4	TL2AR4	3....1
ZMAX	129.60000-	83.98000-	87.22000-	53.94000-	129.60000-	83.98000-	87.22000-	53.94000-	ZMAX
OPCAP	129.60000	83.98000	87.22000	53.94000	129.60000	83.98000	87.22000	53.94000	OPCAP
TLAMT3	.	.	5.66000	2.80000	.	.	.	.	TLAMT3
TLAMT4	.	.	.	.	.	.	5.66000	2.80000	TLAMT4
FTAMT2	8.41000	4.36000	.	.	.	.	.	.	FTAMT2
FTAMT3	.	.	.	.	8.41000	4.36000	.	.	FTAMT3
TLSIZ9	.	.	.48100-	.23800-	.	.	.52100-	.25800-	TLSIZ9
TLSIZ12	.	.	1.21100-	.59900-	.	.	1.31900-	.65200-	TLSIZ12
TLSIZ15	.	.	.82600-	.40900-	.	.	.90000-	.44500-	TLSIZ15
TLSIZ18	.	.	.70200-	.34700-	.	.	.76400-	.37800-	TLSIZ18
FTSIZ9	.74000-	.38400-	.	.	.71500-	.37100-	.	.	FTSIZ9
FTSIZ12	1.86700-	.96800-	.	.	1.80000-	.93300-	.	.	FTSIZ12
FTSIZ15	1.27800-	.66300-	.	.	1.22800-	.63600-	.	.	FTSIZ15
FTSIZ18	1.08500-	.56200-	.	.	1.04300-	.54100-	.	.	FTSIZ18

	FT1AR4	FT2AR4	TL1AR5	TL2AR5	FT1AR5	FT2AR5	HAULSAW1	HAULSAW2	4....1
MAX	129.60000-	83.98000-	87.22000-	53.94000-	129.60000-	83.98000-	3.52000-	3.52000-	ZMAX
PCAP	129.60000	83.98000	87.22000	53.94000	129.60000	83.98000	3.52000	3.52000	OPCAP
LAMT5	.	.	5.66000	2.80000	.	.	.	.	TLAMT5
TAMT4	8.41000	4.36000	.	.	.	.	.	.	FTAMT4
TAMT5	.	.	.	.	8.41000	4.36000	.	.	FTAMT5
LSIZ9	.	.	.55500-	.27400-	.	.	1.00000	.	TLSIZ9
LSIZ12	.	.	1.40400-	.69400-	.	.	.	1.00000	TLSIZ12
LSIZ15	.	.	.96200-	.47600-	.	.	.	.	TLSIZ15
LSIZ18	.	.	.81500-	.40300-	.	.	.	.	TLSIZ18
TSIZ9	.77400-	.40100-	.	.	.82400-	.42700-	.	.	FTSIZ9
TSIZ12	1.96000-	1.01600-	.	.	2.08600-	1.08100-	.	.	FTSIZ12
TSIZ15	1.33700-	.69300-	.	.	1.43000-	.74100-	.	.	FTSIZ15
TSIZ18	1.13500-	.58900-	.	.	1.21100-	.62800-	.	.	FTSIZ18
ARK	.	.	.	.	.	.	.08000-	.08000-	BARK
OGS9	.	.	.	.	.	.	.74900-	.	LOGS9
OGS12	.	.	.	.	.	.	.	.79600-	LOGS12

	HAULSAW3	HAULSAW4	HAULSAW5	HAULSAW6	HAULSAW7	HAULSAW8	HAULCHP1	HAULCHP2	5....1
MAX	3.52000-	3.52000-	3.87000-	3.87000-	3.87000-	3.87000-	3.52000-	3.87000-	ZMAX
PCAP	3.52000	3.52000	3.87000	3.87000	3.87000	3.87000	3.52000	3.87000	OPCAP
LSIZ9	.	.	.	.	.	.	1.00000	.	TLSIZ9
LSIZ12	.	.	.	.	.	.	1.00000	.	TLSIZ12
LSIZ15	1.00000	.	.	.	.	.	1.00000	.	TLSIZ15
LSIZ18	.	1.00000	.	.	.	.	1.00000	.	TLSIZ18
TSIZ9	.	.	1.00000	.	.	.	.	1.00000	FTSIZ9
TSIZ12	.	.	.	1.00000	.	.	.	.	FTSIZ12
TSIZ15	.	.	.	.	1.00000	.	.	.	FTSIZ15
TSIZ18	.	.	.	.	.	1.00000	.	.	FTSIZ18
ARK	.08000-	.08000-	.08000-	.08000-	.08000-	.08000-	.08000-	.08000-	BARK
RAN-TOP	.	.	.06000-	.05000-	.04000-	.03000-	.	.06000-	BRAN-TOP
HIPS	.	.	.	.	.	.	.78200-	.73200-	CHIPS
OGS9	.	.	.70000-	.	.	.	.	.	LOGS9
OGS12	.	.	.	.75200-	.	.	.	.	LOGS12
OGS15	.78200-	.	.	.	.74800-	.	.	.	LOGS15
OGS18	.	.81000-	.	.	.	.78400-	.	.	LOGS18

	HAULCHP3	HAULCHP4	HAULCHP5	HAULWAF1	HAULWAF2	HAULWAF3	HAULWAF4	HAULWAF5	6....1
MAX	3.87000-	3.87000-	3.87000-	3.52000-	3.87000-	3.87000-	3.87000-	3.87000-	ZMAX
PCAP	3.87000	3.87000	3.87000	3.52000	3.87000	3.87000	3.87000	3.87000	OPCAP
LSIZ9	.	.	.	1.00000	.	.	.	.	TLSIZ9
LSIZ12	.	.	.	1.00000	.	.	.	.	TLSIZ12
LSIZ15	.	.	.	1.00000	.	.	.	.	TLSIZ15
LSIZ18	.	.	.	1.00000	.	.	.	.	TLSIZ18
TSIZ9	.	.	.	.	1.00000	.	.	.	FTSIZ9
TSIZ12	1.00000	.	.	.	.	1.00000	.	.	FTSIZ12
TSIZ15	.	1.00000	.	.	.	.	1.00000	.	FTSIZ15
TSIZ18	.	.	1.00000	.	.	.	.	1.00000	FTSIZ18
ARK	.08000-	.08000-	.08000-	.	.	.	.	.	BARK
RAN-TOP	.05000-	.04000-	.03000-	.	.	.	.	.	BRAN-TOP
HIPS	.74000-	.74800-	.75600-	.	.	.	.	.	CHIPS
AFERCON	.	.	.	.43500-	.40700-	.41200-	.41600-	.42100-	WAFERCON

	HAULPLY1	HAULPLY2	HAULPLY3	HAULPLY4	HAULPLY5	HAULPLY6	HAULPLY7	HAULPLY8	7....1
ZMAX	3.52000-	3.52000-	3.52000-	3.52000-	3.87000-	3.87000-	3.87000-	3.87000-	ZMAX
OPCAP	3.52000	3.52000	3.52000	3.52000	3.87000	3.87000	3.87000	3.87000	OPCAP
TLSIZ9	1.00000	.	.	.	.	.	.	.	TLSIZ9
TLSIZ12	.	1.00000		.	.	.	.	.	TLSIZ12
TLSIZ15	.	.	1.00000	.	.	.	.	.	TLSIZ15
TLSIZ18	.	.	.	1.00000	.	.	.	.	TLSIZ18
FTSIZ9	.	.	.	.	1.00000	.	.	.	FTSIZ9
FTSIZ12	.	.	.	.	.	1.00000	.	.	FTSIZ12
FTSIZ15	.	.	.	.	.	.	1.00000	.	FTSIZ15
FTSIZ18	.	.	.	.	.	.	.	1.00000	FTSIZ18
BARK	.08000-	.08000-	.08000-	.08000-	.08000-	.08000-	.08000-	.08000-	BARK
BRAN-TOP	.	.	.	.	.06000-	.05000-	.04000-	.03000-	BRAN-TOP
LOG8	.23000-	.34500-	.40900-	.09200-	.21500-	.32600-	.39100-	.08900-	LOG8
LOG11	.	.17300-	.30700-	.36800-	.	.16300-	.29300-	.35600-	LOG11
LOG14	.	.	.15300-	.32200-	.		.14700-	.31200-	LOG14
LOG17	.	.	.	.13800-	.	.	.	.13400-	LOG17
LOGCHIP	.69000-	.40200-	.05200-	.	.64500-	.38100-	.05000-	.	LOGCHIP

	STUDMILL	STUDCAP	DIMMILL	DIMCAP	TWINMILL	TWINCAP	BOARDMIL	BOARDCAP	8....1
ZMAX	15.33000-	5.34000-	15.33000-	5.34000-	36.70000-	7.13000-	17.06000-	5.95000-	ZMAX
OPCAP	15.33000	5.34000	15.33000	5.34000	36.70000	7.13000	17.06000	5.95000	OPCAP
CHIPS	1.45000-	.	1.45000-	.	.72800-	.	1.45000-	.	CHIPS
LOGS9	.48800	.	.48800	.	.45800	.	.47500	.	LOGS9
LOGS12	.56800	.	.56800	.	.45800	.	47500	.	LOGS12
LOGS15	.60000	.	.60000	.	.45800	.	.47500	.	LOGS15
LOGS18	.62600	.	.62600	.	.45800	.	.47500	.	LOGS18
STUDTRAN	1.00000-	1.00000	.	.	.	.	.	.	STUDTRAN
CAPSTUD	.	45.20000	.	.	.	.	.	.	CAPSTUD
LIMS&D	.	1.00000	.	1.00000	.	.	.	.	LIMS&D
DIMTRAN	.	.	1.00000-	1.00000	.	.	.	.	DIMTRAN
CAPDIM	.	.	.	45.20000	.	.	.	.	CAPDIM
TWINTRAN	.	.	.	.	1.00000-	1.00000	.	.	TWINTRAN
CAPTWIN	.	.	.	.	.	59.23000	.	.	CAPTWIN
LIMTWIN	.	.	.	.	.	1.00000	.	.	LIMTWIN
BOARDTRN	.	.	.	.	.	.	1.00000-	1.00000	BOARDTRN
CAPBOARD	.	.	.	.	.	.	.	59.23000	CAPBOARD
LIMBOARD	.	.	.	.	.	.	.	1.00000	LIMBOARD
STSLETBD	.	.03300-	.	.	.	.	.	.	STSLETBD
STCONBD	.	.01400-	.	.	.	.	.	.	STCONBD
STSTDBD	.	.02000-	.	.	.	.	.	.	STSTDBD
STUTILBD	.	.01300-	.	.	.	.	.	.	STUTILBD
STECONBD	.	.00100-	.	.	.	.	.	.	STECONBD
STSTUD	.	.79700-	.	.	.	.	.	.	STSTUD
STECON	.	.12300-	.	.	.	.	.	.	STECON
DMSLETBD	.	.	.	.03300-	.	.	.	.	DMSLETBD
DMCONBD	.	.	.	.01400-	.	.	.	.	DMCONBD
DMSTDBD	.	.	.	.02000-	.	.	.	.	DMSTDBD
DMUTILBD	.	.	.	.01300-	.	.	.	.	DMUTILBD
DMECONBD	.	.	.	.00100-	.	.	.	.	DMECONBD
DMCONST	.	.	.	.44500-	.	.	.	.	DMCONST
DMSTAND	.	.	.	.14500-	.	.	.	.	DMSTAND
DMUTIL	.	.	.	.20600-	.	.	.	.	DMUTIL
DMECON	.	.	.	.12300-	.	.	.	.	DMECON
TWINBD1	.	.	.	.	.	.17000-	.	.	TWINBD1
TWINBD2A	.	.	.	.	.	.24000-	.	.	TWINBD2A
TWINBD2B	.	.	.	.	.	.25000-	.	.	TWINBD2B
TWINBD3	.	.	.	.	.	.34000-	.	.	TWINBD3
BOARD1	.	.	.	.	.	.	.	.20000-	BOARD1
BOARD2A	.	.	.	.	.	.	.	.25000-	BOARD2A
BOARD2B	.	.	.	.	.	.	.	.25000-	BOARD2B
BOARD3	.	.	.	.	.	.	.	.30000-	BOARD3

	PULPMILL	PULPCAP	SPRUCE	PARTMILL	PARTCAP	WAFERMIL	WAFERCAP	PLYMILL1	9....1
ZMAX	53.62000-	99.40000-	35.00000-	52.33000-	10.10000-	76.55000-	26.55000-	49.08000-	ZMAX
OPCAP	53.62000	99.40000	35.00000	52.33000	10.10000	76.55000	26.55000	49.08000	OPCAP
CHIPS	1.00000	.	.	1.00000	.	.	.	.27000-	CHIPS
LOG8	.	.	.	.	.	.	.	1.00000	LOG8
PULPTRAN	.31450-	1.00000	.	.	.	.	.	.	PULPTRAN
CAPPULP	.	744.13000	.	.	.	.	.	.	CAPPULP
LIMPULP	.	1.00000	.	.	.	.	.	.	LIMPULP
SPNEED	.	1.00000	2.13700-	.	.	.	.	.	SPNEED
PBTRAN	.	.	.	.78900-	1.00000	.	.	.	PBTRAN
CAPPART	.	.	.	.	81.59000	.	.	.	CAPPART
LIMPB	.	.	.	.	1.00000	.	.	.	LIMPB
WAFERCON	.	.	.	.	.	1.00000	.	.	WAFERCON
WAFTRAN	.	.	.	.	.	1.00000-	1.00000	.	WAFTRAN
CAPWAFER	.	.	.	.	.	.	265.16000	.	CAPWAFER
LIMWAFER	.	.	.	.	.	.	1.00000	.	LIMWAFER
PLYCON	.	.	.	.	.	.	.	.43000-	PLYCON
PLYTRIM	.	.	.	.	.	.	.	.19000-	PLYTRIM
PULPPROD	.	1.00000-	.	.	.	.	.	.	PULPPROD
PBPROD	.	.	.	.	1.00000-	.	.	.	PBPROD
WAFERPRO	.	.	.	.	.	.	1.00000-	.	WAFERPRO

	PLYMILL2	PLYMILL3	PLYMILL4	PLYCAP	CHIPLOG	TAX&AD	AVALCHIP	SLECTBD	10....1
ZMAX	55.92000-	60.49000-	62.77000-	25.54000-	7.94000-	.02750-	.00010	305.00000	ZMAX
OPCAP	55.92000	60.49000	62.77000	25.54000	7.94000	.02750	.	.	OPCAP
CHIPS	.15000-	.09000-	.06000-	.	1.00000-	.	2.94500	.	CHIPS
LOG11	1.00000	.	.	.	.	.	.	.	LOG11
LOG14	.	1.00000	.	.	.	.	.	.	LOG14
LOG17	.	.	1.00000	.	.	.	.	.	LOG17
PLYCON	.49000-	.53000-	.55000-	1.00000	.	.	.	.	PLYCON
CAPPLY	.	.	.	207.28000	.	.	.	.	CAPPLY
LIMPLY	.	.	.	1.00000	.	.	.	.	LIMPLY
PLYTRIM	.25000-	.27000-	.28000-	.	.	.	.	.	PLYTRIM
LOGCHIP	.	.	.	.	1.00000	.	.	.	LOGCHIP
AD&TAX	.	.	.	.	.	1.00000-	.	305.00000	AD&TAX
PLYPROD	.	.	.	1.00000-	.	.	.	.	PLYPROD
STSLETBD	.	.	.	.	.	.	.	1.54700	STSLETBD

	CONSTBD	STANDBD	UTILBD	ECONOBD	SLECTBDD	CONSTBDD	STANDBDD	UTILBDD	11....1
ZMAX	200.00000	195.00000	120.00000	85.00000	305.00000	200.00000	195.00000	120.00000	ZMAX
AD&TAX	200.00000	195.00000	120.00000	85.00000	305.00000	200.00000	195.00000	120.00000	AD&TAX
STCONBD	1.54700	.	.	.	.	.	.	.	STCONBD
STSTDBD	.	1.54700	.	.	.	.	.	.	STSTDBD
STUTILBD	.	.	1.54700	.	.	.	.	.	STUTILBD
STECONBD	.	.	.	1.54700	.	.	.	.	STECONBD
DMSLETBD	.	.	.	.	1.54700	.	.	.	DMSLETBD
DMCONBD	.	.	.	.	.	1.54700	.	.	DMCONBD
DMSTDBD	.	.	.	.	.	.	1.54700	.	DMSTDBD
DMUTILBD	.	.	.	.	.	.	.	1.54700	DMUTILBD

	ECONOBDD	CONSTDIM	STANDIM	UTILDIM	ECONODIM	STUD	ECONOSTD	BD#1BTR	12....1
ZMAX	85.00000	152.00000	152.00000	103.00000	85.00000	149.00000	85.00000	425.00000	ZMAX
AD&TAX	85.00000	152.00000	152.00000	103.00000	85.00000	149.00000	85.00000	425.00000	AD&TAX
STSTUD	.	.	.	.	.	1.54700	.	.	STSTUD
STECON	.	.	.	.	.	.	1.54700	.	STECON
DMECONBD	1.54700	.	.	.	.	.	.	.	DMECONBD
DMCONST	.	1.54700	.	.	.	.	.	.	DMCONST
DMSTAND	.	.	1.54700	.	.	.	.	.	DMSTAND
DMUTIL	.	.	.	1.54700	.	.	.	.	DMUTIL
DMECON	.	.	.	.	1.54700	.	.	.	DMECON
BOARD1	.	.	.	.	.	.	.	2.32400	BOARD1

	BD#2A	BD#2B	BD#3	BD#1BTRT	BD#2AT	BD#2BT	BD#3T	PULP	13....1
ZMAX	280.00000	200.00000	150.00000	425.00000	280.00000	200.00000	150.00000	510.00000	ZMAX
AD&TAX	280.00000	200.00000	150.00000	425.00000	280.00000	200.00000	150.00000	510.00000	AD&TAX
PULPPROD	.	.	.	.	.	.	.	1.00000	PULPPROD
TWINBD1	.	.	.	2.32400	.	.	.	.	TWINBD1
TWINBD2A	.	.	.	.	2.32400	.	.	.	TWINBD2A
TWINBD2B	.	.	.	.	.	2.32400	.	.	TWINBD2B
TWINBD3	.	.	.	.	.	.	2.32400	.	TWINBD3
BOARD2A	2.32400	.	.	.	.	.	.	.	BOARD2A
BOARD2B	.	2.32400	.	.	.	.	.	.	BOARD2B
BOARD3	.	.	2.32400	.	.	.	.	.	BOARD3

	PB3/4	PB5/8	PB1/2	PB3/8	WAF1/4	WAF5/16	WAF3/8	WAF7/16	14....1
ZMAX	203.04000	211.86000	211.86000	229.32000	317.80000	296.61000	264.83000	248.18000	ZMAX
AD&TAX	203.04000	211.86000	211.86000	229.32000	317.80000	296.61000	264.83000	248.18000	AD&TAX
PBPROD	1.00000	1.00000	1.00000	1.00000	.	.	.	.	PBPROD
WAFERPRO	.	.	.	.	1.00000	1.00000	1.00000	1.00000	WAFERPRO

	WAF5/8TG	PLY1/4	PLY1/2	PLY3/4	TRIMROND	HOGFUEL	MONEYSTD	MONEYDIM	15....1
ZMAX	286.02000	557.94000	337.46000	284.04000	8.14000	6.11000	.12000-	.12000-	ZMAX
BARK	.	.	.	.	.	1.00000	.	.	BARK
BRAN-TOP	.	.	.	.	.	1.00000	.	.	BRAN-TOP
CAPSTUD	.	.	.	.	.	.	1.00000-	.	CAPSTUD
CAPDIM	.	.	.	.	.	.	.	1.00000-	CAPDIM
PLYTRIM	.	.	.	.	1.00000	.	.	.	PLYTRIM
AD&TAX	286.02000	557.94000	337.46000	284.04000	.	.	.	.	AD&TAX
WAFERPRO	1.00000	.	.	.	.	.	.	.	WAFERPRO
PLYPROD	.	1.00000	1.00000	1.00000	.	.	.	.	PLYPROD

	MONEYTWN	MONEYBOR	MONEYPLP	MONEYPRT	MONEYWAF	MONEYPLY	OPERAT$$	RHS1	16....1
ZMAX	.12000-	.12000-	.12000-	.12000-	.12000-	.12000-	.24000-	.	ZMAX
OPCAP	.	.	.	.	.	.	1.00000-	.	OPCAP
ALLOWCUT	.	.	.	.	.	.	.	2268000.0	ALLOWCUT
LIMHAR1	.	.	.	.	.	.	.	1910.0000	LIMHAR1
LIMHAR2	.	.	.	.	.	.	.	5853.0000	LIMHAR2
LIMHAR3	.	.	.	.	.	.	.	4431.0000	LIMHAR3
LIMHAR4	.	.	.	.	.	.	.	3876.0000	LIMHAR4
LIMHAR5	.	.	.	.	.	.	.	2089.0000	LIMHAR5
LIMS&D	.	.	.	.	.	.	.	42250.000	LIMS&D
CAPTWIN	1.00000-	.	.	.	.	.	.	.	CAPTWIN
LIMTWIN	.	.	.	.	.	.	.	45312.000	LIMTWIN
CAPBOARD	.	1.00000-	.	.	.	.	.	.	CAPBOARD
LIMBOARD	.	.	.	.	.	.	.	38000.000	LIMBOARD
CAPPULP	.	.	1.00000-	.	.	.	.	.	CAPPULP
LIMPULP	.	.	.	.	.	.	.	157500.00	LIMPULP
CAPPART	.	.	.	1.00000-	.	.	.	.	CAPPART
LIMPB	.	.	.	.	.	.	.	100359.00	LIMPB
CAPWAFER	.	.	.	.	1.00000-	.	.	.	CAPWAFER
LIMWAFER	.	.	.	.	.	.	.	141600.00	LIMWAFER
CAPPLY	.	.	.	.	.	1.00000-	.	.	CAPPLY
LIMPLY	.	.	.	.	.	.	.	27450.000	LIMPLY

APPENDIX 10. COMPUTER PRINTOUT OF OPTIMAL SOLUTION

REFERENCE MATRIX SOLUTION

SOLUTION (OPTIMAL)

TIME = 0.03 MINS. ITERATION NUMBER = 101

...NAME...	...ACTIVITY...	DEFINED AS
FUNCTIONAL	24852490.8509	ZMAX
RESTRAINTS		RHS1

SECTION 1 - ROWS

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
1	ZMAX	BS	24952490.8509	24952490.8509-	NONE	NONE	1.00000
2	OPCAP	UL	.	.	NONE	.	.24000-
3	ALLOWCUT	[illegible]	937062.11737	1330937.88263	NONE	2268000.00000	.
4	LIMHAR1	BS	.	1910.00000	NONE	1910.00000	.
5	LIMHAR2	BS	.	5853.00000	NONE	5853 00000	.
6	LIMHAR3	BS	.	4431.00000	NONE	4431.00000	.
7	LIMHAR4	BS	3495.53766	380.46234	NONE	3876.00000	.
8	LIMHAR5	UL	2089.00000	.	NONE	2089.00000	249.44053-
9	TLAMT1	BS	.	.	NONE	.	.
10	TLAMT2	BS	.	.	NONE	.	.
11	TLAMT3	BS	.	.	NONE	.	.
12	TLAMT4	UL	.	.	NONE	.	.58244-
13	TLAMT5	UL	.	.	NONE	.	1.97632-
14	FTAMT1	BS	.	.	NONE	.	.
15	FTAMT2	BS	.	.	NONE	.	.
16	FTAMT3	BS	.	.	NONE	.	.
17	FTAMT4	UL	.	.	NONE	.	.54458-
18	FTAMT5	UL	.	.	NONE	.	1.84732-
19	TLSIZ9	UL	.	.	NONE	.	33.66475-
20	TLSIZ12	UL	.	.	NONE	.	28.57890-
21	TLSIZ15	UL	.	.	NONE	.	33.75025-
22	TLSIZ18	UL	.	.	NONE	.	33.82103-
23	FTSIZ9	UL	.	.	NONE	.	31.10944-
24	FTSIZ12	UL	.	.	NONE	.	31.55057-
25	FTSIZ15	UL	.	.	NONE	.	31.90348-
26	FTSIZ18	UL	.	.	NONE	.	32.34461-
27	BARK	BS	18013.24848-	18013.24848	NONE	.	.
28	BRAN-TOP	UL	.	.	NONE	.	6.11000-
29	CHIPS	UL	.	.	NONE	.	38.70608-
30	LOGS9	UL	.	.	NONE	.	50.77377-
31	LOGS12	UL	.	.	NONE	.	41.38656-
32	LOGS15	UL	.	.	NONE	.	48.74048-
33	LOGS18	UL	.	.	NONE	.	47.14300-
34	LOG8	UL	.	.	NONE	.	41.22305-
35	LOG11	UL	.	.	NONE	.	41.15513-
36	LOG14	UL	.	.	NONE	.	41.70876-
37	LOG17	UL	.	.	NONE	.	41.99178-
38	STUDTRAN	UL	.	.	NONE	.	69.92635-
39	CAPSTUD	UL	.	.	NONE	.	.12000-
40	LIMS&D	UL	42250.00000	.	NONE	42250.00000	10.19626-
41	DIMTRAN	UL	.	.	NONE	.	65.02193-
42	CAPDIM	UL	.	.	NONE	.	.12000-
43	TWINTRAN	UL	.	.	NONE	.	83.98694-
44	CAPTWIN	UL	.	.	NONE	.	.12000-
45	LIMTWIN	BS	.	45312.00000	NONE	45312.00000	.
46	BOARDTRN	UL	.	.	NONE	.	54.35139-
47	CAPBOARD	UL	.	.	NONE	.	.12000-
48	LIMBOARD	UL	38000.00000	.	NONE	38000.00000	35.06791-
49	PULPTRAN	UL	.	.	NONE	.	280.05740-
50	CAPPULP	UL	.	.	NONE	.	.12000-
51	LIMPULP	BS	.	157500.00000	NONE	157500.00000	.
52	SPNEED	BS	.	.	NONE	.	.
53	PBTRAN	UL	.	.	NONE	.	131.29946-
54	CAPPART	UL	.	.	NONE	.	.12000-
55	LIMPB	UL	100359.00000	.	NONE	100359.00000	67.88592-
56	WAFERCON	UL	.	.	NONE	.	88.22663-
57	WAFTRAN	UL	.	.	NONE	.	183.14863-
58	CAPWAFER	UL	.	.	NONE	.	.12000-
59	LIMWAFER	UL	141600.00000	.	NONE	141600.00000	59.07319-
60	PLYCON	UL	.	.	NONE	.	209.50003-
61	CAPPLY	UL	.	.	NONE	.	.12000-
62	LIMPLY	UL	27450.00000	.	NONE	27450.00000	272.87102-
63	PLYTRIM	UL	.	.	NONE	.	8.14000-
64	LOGCHIP	UL	.	.	NONE	.	28.86048-
65	AD&TAX	UL	.	.	NONE	.	.03410-
66	PULPPROD	UL	.	.	NONE	.	492.60900-
67	PBPROD	UL	.	.	NONE	.	221.50019-
68	WAFERPRO	UL	.	.	NONE	.	306.96302-
69	PLYPROD	UL	.	.	NONE	.	538.91425-
70	STSLETBD	UL	.	.	NONE	.	190.43277-
71	STCONBD	UL	.	.	NONE	.	124.87395-
72	STSTDBD	UL	.	.	NONE	.	121.75210-
73	STUTILBD	UL	.	.	NONE	.	74.92437-
74	STECONBD	UL	.	.	NONE	.	53.07143-
75	STSTUD	UL	.	.	NONE	.	93.03109-
76	STECON	UL	.	.	NONE	.	53.07143-
77	DMSLETBD	UL	.	.	NONE	.	190.43277-
78	DMCONBD	UL	.	.	NONE	.	124.87395-
79	DMSTDBD	UL	.	.	NONE	.	121.75210-
80	DMUTILBD	UL	.	.	NONE	.	74.92437-
81	DMECONBD	UL	.	.	NONE	.	53.07143-
82	DMCONST	UL	.	.	NONE	.	94.90420-
83	DMSTAND	UL	.	.	NONE	.	94.90420-
84	DMUTIL	UL	.	.	NONE	.	64.31008-
85	DMECON	UL	.	.	NONE	.	53.07143-
86	TWINBD1	UL	.	.	NONE	.	176.63834-
87	TWINBD2A	UL	.	.	NONE	.	116.37349-
88	TWINBD2B	UL	.	.	NONE	.	83.12392-
89	TWINBD3	UL	.	.	NONE	.	62.34294-
90	BOARD1	UL	.	.	NONE	.	176.63834-
91	BOARD2A	UL	.	.	NONE	.	116.37349-
92	BOARD2B	UL	.	.	NONE	.	83.12392-
93	BOARD3	UL	.	.	NONE	.	62.34294-

SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
94	HARVEST1	LL	.	34.50000-	.	NONE	42.78000-
95	HARVEST2	LL	.	44.65000-	.	NONE	55.36600-
96	HARVEST3	LL	.	61.10000-	.	NONE	75.76400-
97	HARVEST4	BS	1633.71515	75.67000-	.	NONE	.
98	HARVEST5	BS	.	84.13000-	.	NONE	.
99	HARVES1A	LL	.	34.50000-	.	NONE	42.78000-
100	HARVES2A	LL	.	44.65000-	.	NONE	55.36600-
101	HARVES3A	LL	.	61.10000-	.	NONE	75.76400-
102	HARVES4A	BS	1861.82251	75.67000-	.	NONE	.
103	HARVES5A	BS	2089.00000	84.13000-	.	NONE	.
104	TL1AR1	LL	.	87.22000-	.	NONE	11.27929-
105	TL2AR1	LL	.	53.94000-	.	NONE	19.67656-
106	FT1AR1	LL	.	129.60000-	.	NONE	19.16576-
107	FT2AR1	LL	.	83.98000-	.	NONE	30.76252-
108	TL1AR2	LL	.	87.22000-	.	NONE	1.77808-
109	TL2AR2	LL	.	53.94000-	.	NONE	14.24100-
110	FT1AR2	LL	.	129.60000-	.	NONE	2.91156-
111	FT2AR2	LL	.	83.98000-	.	NONE	22.31855-
112	TL1AR3	LL	.	87.22000-	.	NONE	5.73093-
113	TL2AR3	LL	.	53.94000-	.	NONE	16.21488-
114	FT1AR3	LL	.	129.60000-	.	NONE	8.75683-
115	FT2AR3	LL	.	83.98000-	.	NONE	25.36787-
116	TL1AR4	BS	46500.26696	87.22000-	.	NONE	.
117	TL2AR4	LL	.	53.94000-	.	NONE	13.39427-
118	FT1AR4	BS	38144.11635	129.60000-	.	NONE	.
119	FT2AR4	LL	.	83.98000-	.	NONE	20.81921-
120	TL1AR5	LL	.	87.22000-	.	NONE	.49819-
121	TL2AR5	LL	.	53.94000-	.	NONE	13.66641-
122	FT1AR5	BS	47567.59810	129.60000-	.	NONE	.
123	FT2AR5	LL	.	83.98000-	.	NONE	20.84673-
124	HAULSAW1	BS	24226.63909	3.52000-	.	NONE	.
125	HAULSAW2	BS	52824.12060	3.52000-	.	NONE	.
126	HAULSAW3	BS	41850.24027	3.52000-	.	NONE	.
127	HAULSAW4	BS	35526.20396	3.52000-	.	NONE	.
128	HAULSAW5	BS	29317.49618	3.87000-	.	NONE	.
129	HAULSAW6	LL	.	3.87000-	.	NONE	4.92118-
130	HAULSAW7	BS	14268.86646	3.87000-	.	NONE	.
131	HAULSAW8	BS	20053.92193	3.87000-	.	NONE	.
132	HAULCHP1	LL	.	3.52000-	.	NONE	103.91158-
133	HAULCHP2	LL	.	3.87000-	.	NONE	7.20879-
134	HAULCHP3	LL	.	3.87000-	.	NONE	7.40137-
135	HAULCHP4	LL	.	3.87000-	.	NONE	7.50573-
136	HAULCHP5	LL	.	3.87000-	.	NONE	7.69832-
137	HAULWAF1	LL	.	3.52000-	.	NONE	95.80115-
138	HAULWAF2	BS	39401.75071	3.87000-	.	NONE	.
139	HAULWAF3	BS	173988.47767	3.87000-	.	NONE	.
140	HAULWAF4	BS	104751.48237	3.87000-	.	NONE	.
141	HAULWAF5	BS	24474.15200	3.87000-	.	NONE	.
142	HAULPLY1	LL	.	3.52000-	.	NONE	8.63452-
143	HAULPLY2	BS	8509.73152	3.52000-	.	NONE	.
144	HAULPLY3	LL	.	3.52000-	.	NONE	.73801-
145	HAULPLY4	LL	.	3.52000-	.	NONE	.02313-
146	HAULPLY5	LL	.	3.87000-	.	NONE	8.06367-
147	HAULPLY6	LL	.	3.87000-	.	NONE	4.90103-
148	HAULPLY7	LL	.	3.87000-	.	NONE	.70700-
149	HAULPLY8	BS	56369.85942	3.87000-	.	NONE	.
150	STUDMILL	BS	42250.00000	15.33000-	.	NONE	.
151	STUDCAP	BS	42250.00000	5.34000-	.	NONE	.
152	DIMMILL	LL	.	15.33000-	.	NONE	4.90442-
153	DIMCAP	BS	.	5.34000-	.	NONE	.
154	TWINMILL	LL	.	36.70000-	.	NONE	19.46710-
155	TWINCAP	BS	.	7.13000-	.	NONE	.
156	BOARDMIL	BS	38000.00000	17.06000-	.	NONE	.
157	BOARDCAP	BS	38000.00000	5.95000-	.	NONE	.
158	PULPMILL	LL	.	53.62000-	.	NONE	17.11683-
159	PULPCAP	BS	.	99.40000-	.	NONE	.
160	SPRUCE	LL	.	35.00000-	.	NONE	43.40000-
161	PARTMILL	BS	127187.71863	52.33000-	.	NONE	.
162	PARTCAP	BS	100359.00000	10.10000-	.	NONE	.
163	WAFERMIL	BS	141600.00000	76.55000-	.	NONE	.
164	WAFERCAP	BS	141600.00000	26.55000-	.	NONE	.
165	PLYMILL1	BS	7952.77486	49.08000-	.	NONE	.
166	PLYMILL2	BS	21539.85350	55.92000-	.	NONE	.
167	PLYMILL3	BS	17587.39614	60.49000-	.	NONE	.
168	PLYMILL4	BS	7553.56116	62.77000-	.	NONE	.
169	PLYCAP	BS	27450.00000	25.54000-	.	NONE	.
170	CHIPLOG	BS	3420.91207	7.94000-	.	NONE	.
171	TAX&AD	BS	91449622.6033	.02750-	.	NONE	.
172	AVALCHIP	LL	.	.00010	.	NONE	113.98930-
173	SLECTBD	BS	901.26050	305.00000	.	NONE	.
174	CONSTBD	BS	382.35294	200.00000	.	NONE	.
175	STANDBD	BS	546.21849	195.00000	.	NONE	.
176	UTILBD	BS	355.04202	120.00000	.	NONE	.
177	ECONOBD	BS	27.31092	85.00000	.	NONE	.
178	SLECTBDD	BS	.	305.00000	.	NONE	.
179	CONSTBDD	BS	.	200.00000	.	NONE	.
180	STANDBDD	BS	.	195.00000	.	NONE	.
181	UTILBDD	BS	.	120.00000	.	NONE	.
182	ECONOBDD	BS	.	85.00000	.	NONE	.
183	CONSTDIM	BS	.	152.00000	.	NONE	.
184	STANDIM	BS	.	152.00000	.	NONE	.
185	UTILDIM	BS	.	103.00000	.	NONE	.
186	ECONODIM	BS	.	85.00000	.	NONE	.
187	STUD	BS	21766.80672	149.00000	.	NONE	.
188	ECONOSTD	BS	3359.24370	85.00000	.	NONE	.
189	BD#1BTR	BS	3270.22375	425.00000	.	NONE	.
190	BD#2A	BS	4087.77969	280.00000	.	NONE	.
191	BD#2B	BS	4087.77969	200.00000	.	NONE	.
192	BD#3	BS	4905.33563	150.00000	.	NONE	.
193	BD#1BTRT	BS	.	425.00000	.	NONE	.

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
194	BD#2AT	BS	.	280.00000	.	NONE	.
195	BD#2BT	BS	.	200.00000	.	NONE	.
196	BD#3T	BS	.	150.00000	.	NONE	.
197	PULP	BS	.	510.00000	.	NONE	.
198	PB3/4	LL	.	203.04000	.	NONE	25.38385-
199	PB5/8	LL	.	211.86000	.	NONE	16.86461-
200	PB1/2	LL	.	211.86000	.	NONE	16.86461-
201	PB3/8	BS	100359.00000	229.32000	.	NONE	.
202	WAF1/4	BS	141600.00000	317.80000	.	NONE	.
203	WAF5/16	LL	.	296.61000	.	NONE	20.46742-
204	WAF3/8	LL	.	264.83000	.	NONE	51.16372-
205	WAF7/16	LL	.	248.18000	.	NONE	67.24596-
206	WAF5/8TG	LL	.	286.02000	.	NONE	30.69630-
207	PLY1/4	BS	27450.00000	557.94000	.	NONE	.
208	PLY1/2	LL	.	337.46000	.	NONE	212.96163-
209	PLY3/4	LL	.	284.04000	.	NONE	264.56001-
210	TRIMROND	BS	13759.58468	8.14000	.	NONE	.
211	HOGFUEL	BS	4622.51787	6.11000	.	NONE	.
212	MONEYSTD	BS	1909700.00000	.12000-	.	NONE	.
213	MONEYDIM	BS	.	.12000-	.	NONE	.
214	MONEYTWN	BS	.	.12000-	.	NONE	.
215	MONEYBOR	BS	2250740.00000	.12000-	.	NONE	.
216	MONEYPLP	BS	.	.12000-	.	NONE	.
217	MONEYPRT	BS	8188290.80998	.12000-	.	NONE	.
218	MONEYWAF	BS	37546655.9995	.12000-	.	NONE	.
219	MONEYPLY	BS	5689835.99999	.12000-	.	NONE	.
220	OPERAT$$	BS	48360606.1442	.24000-	.	NONE	.

APPENDIX 11. RANGE REPORT OF OPTIMAL SOLUTION

REFERENCE MATRIX RANGE REPORT

SECTION 1 - ROWS AT LIMIT LEVEL

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	LOWER ACTIVITY	...UNIT COST..	..UPPER COST..	LIMITING	AT
					..UPPER LIMIT.	UPPER ACTIVITY	...UNIT COST..	..LOWER COST..	PROCESS.	AT
2	OPCAP	UL	.	.	NONE	INFINITY-	.24000-		NONE	
					.	48360592.0000	.24000		OPERAT$$	LL
8	LIMHAR5	UL	2089.00000	.	NONE	1767.96313	249.44052-		LIMHAR4	UL
					2089.00000	3660.02026	249.44052		FT1AR4	LL
12	TLAMT4	UL	.	.	NONE	61292.45313-	.58244-		LIMHAR4	UL
					.	263191.50000	.58244		HARVEST4	LL
13	TLAMT5	UL	.	.	NONE	57465.61328-	1.97632-		LIMHAR4	UL
					.	.	1.97632		HARVEST5	LL
17	FTAMT4	UL	.	.	NONE	65553.62500-	.54458-		LIMHAR4	UL
					.	320792.00000	.54458		HARVES4A	LL
18	FTAMT5	UL	.	.	NONE	61478.57422-	1.84732-		LIMHAR4	UL
					.	300850.37500	1.84732		FT1AR4	LL
19	TLSIZ9	UL	.	.	NONE	24226.63672-	33.66475-		HAULSAW1	LL
					.	27399.52734	33.66475		HAULSAW5	LL
20	TLSIZ12	UL	.	.	NONE	20002.60156-	28.57889-		HAULSAW7	LL
					.	61333.84375	28.57889		HAULSAW1	LL
21	TLSIZ15	UL	.	.	NONE	38651.35937-	33.75024-		LIMHAR4	UL
					.	13648.47656	33.75024		HAULSAW7	LL
22	TLSIZ18	UL	.	.	NONE	30431.28516-	33.82101-		HAULWAF5	LL
					.	19410.21484	33.82101		HAULSAW8	LL
23	FTSIZ9	UL	.	.	NONE	41301.78906-	31.10944-		LIMHAR4	UL
					.	114256.18750	31.10944		HAULWAF5	LL
24	FTSIZ12	UL	.	.	NONE	40800.55469-	31.55057-		LIMHAR4	UL
					.	112869.56250	31.55057		HAULWAF5	LL
25	FTSIZ15	UL	.	.	NONE	40408.24219-	31.90347-		LIMHAR4	UL
					.	111784.31250	31.90347		HAULWAF5	LL
26	FTSIZ18	UL	.	.	NONE	31440.48828-	32.34460-		HAULWAF5	LL
					.	195392.50000	32.34460		FT1AR4	LL
28	BRAN-TOP	UL	.	.	NONE	4622.51562-	6.11000-		HOGFUEL	LL
					.	18013.24609	6.11000		BARK	UL
29	CHIPS	UL	.	.	NONE	9251.33203-	38.70607-		HAULSAW7	LL
					.	3935.80615	38.70607		CHIPLOG	LL
30	LOGS9	UL	.	.	NONE	28911.25391-	50.77376-		LIMHAR4	UL
					.	20522.24609	50.77376		HAULSAW5	LL
31	LOGS12	UL	.	.	NONE	15922.07031-	41.38655-		HAULSAW7	LL
					.	42047.99609	41.38655		HAULSAW2	LL
32	LOGS15	UL	.	.	NONE	30225.36328-	48.74046-		LIMHAR4	UL
					.	10673.10937	48.74046		HAULSAW7	LL
33	LOGS18	UL	.	.	NONE	24649.33984-	47.14299-		HAULWAF5	LL
					.	15722.27344	47.14299		HAULSAW8	LL
34	LOG8	UL	.	.	NONE	9811.16797-	41.22305-		PLYMILL1	LL
					.	24306.83594	41.22305		CHIPLOG	LL
35	LOG11	UL	.	.	NONE	30279.57031-	41.15512-		HAULWAF5	LL
					.	53447.52344	41.15512		PLYMILL4	LL
36	LOG14	UL	.	.	NONE	25199.23828-	41.70876-		HAULWAF5	LL
					.	46152.75391	41.70876		PLYMILL4	LL
37	LOG17	UL	.	.	NONE	9153.97656-	41.99178-		PLYMILL4	LL
					.	43204.39453	41.99178		PLYMILL3	LL
38	STUDTRAN	UL	.	.	NONE	2714.34863-	69.92635-		HAULPLY2	LL
					.	5640.90625	69.92635		HAULSAW7	LL
39	CAPSTUD	UL	.	.	NONE	INFINITY-	.12000-		NONE	
					.	1909699.00000	.12000		MONEYSTD	LL
40	LIMS&D	UL	42250.00000	.	NONE	36609.09375	10.19626-		HAULSAW7	LL
					42250.00000	44964.34863	10.19626		HAULPLY2	LL
41	DIMTRAN	UL	.	.	NONE	.	65.02193-		MONEYDIM	LL
					.	5640.90625	65.02193		HAULSAW7	LL
42	CAPDIM	UL	.	.	NONE	INFINITY-	.12000-		NONE	
					.	.	.12000		MONEYDIM	LL
43	TWINTRAN	UL	.	.	NONE	.	83.98692-		MONEYTWN	LL
					.	45312.00000	83.98692		LIMTWIN	UL
44	CAPTWIN	UL	.	.	NONE	INFINITY-	.12000-		NONE	
					.	.	.12000		MONEYTWN	LL
46	BOARDTRN	UL	.	.	NONE	2714.34863-	54.35138-		HAULPLY2	LL
					.	5834.10938	54.35138		HAULSAW7	LL
47	CAPBOARD	UL	.	.	NONE	INFINITY-	.12000-		NONE	
					.	2250739.00000	.12000		MONEYBOR	LL

...MBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
48	LIMBOARD	UL	38000.00000	.	NONE 38000.00000	32165.89063 40714.34863	35.06790- 35.06790		HAULSAW7 HAULPLY2	LL LL
49	PULPTRAN	UL	.	.	NONE .	. .	280.05737- 280.05737		MONEYPLP SPNEED	LL UL
50	CAPPULP	UL	.	.	NONE .	INFINITY- .	.12000- .12000		NONE MONEYPLP	 LL
53	PBTRAN	UL	.	.	NONE .	7299.30078- 3105.35059	131.29945- 131.29945		HAULSAW7 HAULPLY2	LL LL
54	CAPPART	UL	.	.	NONE .	INFINITY- 8188290.00000	.12000- .12000		NONE MONEYPRT	 LL
55	LIMPB	UL	100359.00000	.	NONE 100359.00000	97253.64941 107658.30078	67.88591- 67.88591		HAULPLY2 HAULSAW7	LL LL
56	WAFERCON	UL	.	.	NONE .	16809.82812- 46502.28125	88.22662- 88.22662		LIMHAR4 HAULWAF5	UL LL
57	WAFTRAN	UL	.	.	NONE .	16809.82812- 46502.28125	183.14862- 183.14862		LIMHAR4 HAULWAF5	UL LL
58	CAPWAFER	UL	.	.	NONE .	INFINITY- 37546640.0000	.12000- .12000		NONE MONEYWAF	 LL
59	LIMWAFER	UL	141600.00000	.	NONE 141600.00000	95097.71875 158409.82812	59.07318- 59.07318		HAULWAF5 LIMHAR4	LL UL
60	PLYCON	UL	.	.	NONE .	11878.15625- 22602.73047	209.50002- 209.50002		HAULWAF5 PLYMILL4	LL LL
61	CAPPLY	UL	.	.	NONE .	INFINITY- 5689835.00000	.12000- .12000		NONE MONEYPLY	 LL
62	LIMPLY	UL	27450.00000	.	NONE 27450.00000	4847.26953 39328.15625	272.87085- 272.87085		PLYMILL4 HAULWAF5	LL LL
63	PLYTRIM	UL	.	.	NONE .	13759.58203- INFINITY	8.14000- 8.14000		TRIMROND NONE	LL
64	LOGCHIP	UL	.	.	NONE .	9251.33203- 3935.80566	28.86047- 28.86047		HAULSAW7 HAULPLY2	LL LL
65	AD&TAX	UL	.	.	NONE .	INFINITY- 91449616.0000	.03410- .03410		NONE TAX&AD	 LL
66	PULPPROD	UL	.	.	NONE .	. INFINITY	492.60889- 492.60889		PULP NONE	LL
67	PBPROD	UL	.	.	NONE .	100358.93750- INFINITY	221.50018- 221.50018		PB3/8 NONE	LL
68	WAFERPRO	UL	.	.	NONE .	141599.93750- INFINITY	306.96289- 306.96289		WAF1/4 NONE	LL
69	PLYPROD	UL	.	.	NONE .	27449.99609- INFINITY	538.91406- 538.91406		PLY1/4 NONE	LL
70	STSLETBD	UL	.	.	NONE .	1394.24976- INFINITY	190.43277- 190.43277		SLECTBD NONE	LL
71	STCONBD	UL	.	.	NONE .	591.49951- INFINITY	124.87395- 124.87395		CONSTBD NONE	LL
72	STSTDBD	UL	.	.	NONE .	844.99951- INFINITY	121.75209- 121.75209		STANDBD NONE	LL
73	STUTILBD	UL	.	.	NONE .	549.24976- INFINITY	74.92436- 74.92436		UTILBD NONE	LL
74	STECONBD	UL	.	.	NONE .	42.24997- INFINITY	53.07143- 53.07143		ECONOBD NONE	LL
75	STSTUD	UL	.	.	NONE .	33673.24609- INFINITY	93.03108- 93.03108		STUD NONE	LL
76	STECON	UL	.	.	NONE .	5196.74609- INFINITY	53.07143- 53.07143		ECONOSTD NONE	LL
77	DMSLETBD	UL	.	.	NONE .	. INFINITY	190.43277- 190.43277		SLECTBDD NONE	LL
78	DMCONBD	UL	.	.	NONE .	. INFINITY	124.87395- 124.87395		CONSTBDD NONE	LL
79	DMSTDBD	UL	.	.	NONE .	. INFINITY	121.75209- 121.75209		STANDBDD NONE	LL
80	DMUTILBD	UL	.	.	NONE .	. INFINITY	74.92436- 74.92436		UTILBDD NONE	LL
81	DMECONBD	UL	.	.	NONE .	. INFINITY	53.07143- 53.07143		ECONOBDD NONE	LL
82	DMCONST	UL	.	.	NONE .	. INFINITY	94.90419- 94.90419		CONSTDIM NONE	LL
83	DMSTAND	UL	.	.	NONE .	. INFINITY	94.90419- 94.90419		STANDIM NONE	LL

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
84	DMUTIL	UL	.	.	NONE .	. INFINITY	64.31007- 64.31007		UTILDIM NONE	LL
85	DMECON	UL	.	.	NONE .	. INFINITY	53.07143- 53.07143		ECONODIM NONE	LL
86	TWINBD1	UL	.	.	NONE .	. INFINITY	176.63834- 176.63834		BD#1BTRT NONE	LL
87	TWINBD2A	UL	.	.	NONE .	. INFINITY	116.37349- 116.37349		BD#2AT NONE	LL
88	TWINBD2B	UL	.	.	NONE .	. INFINITY	83.12392- 83.12392		BD#2BT NONE	LL
89	TWINBD3	UL	.	.	NONE .	. INFINITY	62.34294- 62.34294		BD#3T NONE	LL
90	BOARD1	UL	.	.	NONE .	7599.99609- INFINITY	176.63834- 176.63834		BD#1BTR NONE	LL
91	BOARD2A	UL	.	.	NONE .	9499.99609- INFINITY	116.37349- 116.37349		BD#2A NONE	LL
92	BOARD2B	UL	.	.	NONE .	9499.99609- INFINITY	83.12392- 83.12392		BD#2B NONE	LL
93	BOARD3	UL	.	.	NONE .	11399.98828- INFINITY	62.34294- 62.34294		BD#3 NONE	LL

CTION 2 - COLUMNS AT LIMIT LEVEL

UMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	LOWER ACTIVITY	...UNIT COST..	..UPPER COST..	LIMITING	AT
					..UPPER LIMIT.	UPPER ACTIVITY	...UNIT COST..	..LOWER COST..	PROCESS.	AT
94	HARVEST1	LL	.	34.50000-	.	.	42.78000	INFINITY-	TLAMT1	UL
					NONE	1910.00000	42.78000-	8.28000	LIMHAR1	UL
95	HARVEST2	LL	.	44.64999-	.	.	55.36600	INFINITY-	TLAMT2	UL
					NONE	5853.00000	55.36600-	10.71600	LIMHAR2	UL
96	HARVEST3	LL	.	61.09999-	.	.	75.76399	INFINITY-	TLAMT3	UL
					NONE	4431.00000	75.76399-	14.66400	LIMHAR3	UL
99	HARVES1A	LL	.	34.50000-	.	.	42.78000	INFINITY-	FTAMT1	UL
					NONE	1810.00000	42.78000-	8.28000	LIMHAR1	UL
100	HARVES2A	LL	.	44.64999-	.	.	55.36600	INFINITY-	FTAMT2	UL
					NONE	5853.00000	55.36600-	10.71600	LIMHAR2	UL
101	HARVES3A	LL	.	61.09999-	.	.	75.76399	INFINITY-	FTAMT3	UL
					NONE	4431.00000	75.76399-	14.66400	LIMHAR3	UL
104	TL1AR1	LL	.	87.21999-	.	12472.85156-	11.27929	INFINITY-	LIMHAR4	UL
					NONE	.	11.27929-	75.94070-	TLAMT1	UL
105	TL2AR1	LL	.	53.93999-	.	25570.73828-	19.67656	INFINITY-	LIMHAR4	UL
					NONE	.	19.67656-	34.26343-	TLAMT1	UL
106	FT1AR1	LL	.	129.59999-	.	9102.45313-	19.16576	INFINITY-	LIMHAR4	UL
					NONE	.	19.16576-	110.43423-	FTAMT1	UL
107	FT2AR1	LL	.	83.98000-	.	17558.92578-	30.76251	INFINITY-	LIMHAR4	UL
					NONE	.	30.76251-	53.21748-	FTAMT1	UL
108	TL1AR2	LL	.	87.21999-	.	11347.63672-	1.77808	INFINITY-	LIMHAR4	UL
					NONE	.	1.77808-	85.44190-	TLAMT2	UL
109	TL2AR2	LL	.	53.93999-	.	22928.15234-	14.24099	INFINITY-	LIMHAR4	UL
					NONE	.	14.24099-	39.69899-	TLAMT2	UL
110	FT1AR2	LL	.	129.59999-	.	8164.79688-	2.91156	INFINITY-	LIMHAR4	UL
					NONE	.	2.91156-	126.68843-	FTAMT2	UL
111	FT2AR2	LL	.	83.98000-	.	15746.70312-	22.31854	INFINITY-	LIMHAR4	UL
					NONE	.	22.31854-	61.66145-	FTAMT2	UL
112	TL1AR3	LL	.	87.21999-	.	11784.34375-	5.73093	INFINITY-	LIMHAR4	UL
					NONE	.	5.73093-	81.48905-	TLAMT3	UL
113	TL2AR3	LL	.	53.93999-	.	23820.28516-	16.21487	INFINITY-	LIMHAR4	UL
					NONE	.	16.21487-	37.72511-	TLAMT3	UL
114	FT1AR3	LL	.	129.59999-	.	8478.86719-	8.75683	INFINITY-	LIMHAR4	UL
					NONE	.	8.75683-	120.84316-	FTAMT3	UL
115	FT2AR3	LL	.	83.98000-	.	16356.26953-	25.36786	INFINITY-	LIMHAR4	UL
					NONE	.	25.36786-	58.61214-	FTAMT3	UL
117	TL2AR4	LL	.	53.93999-	.	4477167.00000-	13.39427	INFINITY-	OPERAT$$	LL
					NONE	94070.31250	13.39427-	40.54572-	TL1AR4	LL
119	FT2AR4	LL	.	83.98000-	.	2880374.00000-	20.81920	INFINITY-	OPERAT$$	LL
					NONE	73574.31250	20.81920-	63.16080-	FT1AR4	LL
120	TL1AR5	LL	.	87.21999-	.	.	.49819	INFINITY-	HARVEST5	LL
					NONE	43685.07813	.49819-	86.72180-	HARVEST4	LL
121	TL2AR5	LL	.	53.93999-	.	.	13.66641	INFINITY-	HARVEST5	LL
					NONE	88377.25000	13.66641-	40.27358-	HARVEST4	LL
123	FT2AR5	LL	.	83.98000-	.	2876573 00000-	20.84673	INFINITY-	OPERAT$$	LL
					NONE	91753.06250	20.84673-	63.13327-	FT1AR5	LL
129	HAULSAW6	LL	.	3.87000-	.	21172.96484-	4.92118	INFINITY-	HAULSAW7	LL
					NONE	55914.88672	4.92118-	1.05118	HAULSAW2	LL
132	HAULCHP1	LL	.	3.52000-	.	9276.16797-	103.91158	INFINITY-	HAULSAW7	LL
					NONE	5032.99609	103.91158-	100.39158	HAULPLY2	LL
133	HAULCHP2	LL	.	3.87000-	.	12638.43359-	7.20879	INFINITY-	HAULSAW7	LL
					NONE	5376.78125	7.20879-	3.33879	HAULPLY2	LL
134	HAULCHP3	LL	.	3.87000-	.	12501.80078-	7.40137	INFINITY-	HAULSAW7	LL
					NONE	5318.65625	7.40137-	3.53137	HAULPLY2	LL
135	HAULCHP4	LL		3.87000-	.	12368.09375-	7.50573	INFINITY-	HAULSAW7	LL
					NONE	5261.76953	7.50573-	3.63573	HAULPLY2	LL
136	HAULCHP5	LL	.	3.87000-	.	12237.21094-	7.69831	INFINITY-	HAULSAW7	LL
					NONE	5206.08984	7.69831-	3.82831	HAULPLY2	LL
137	HAULWAF1	LL	.	3.52000-	.	42965.01562-	95.80115	INFINITY-	HAULSAW7	LL
					NONE	12672.15234	95.80115-	92.28115	LIMHAR4	UL
142	HAULPLY1	LL	.	3.52000-	.	12721.12109-	8.63452	INFINITY-	HAULSAW7	LL
					NONE	5411.96094	8.63452-	5.11452	HAULPLY2	LL
144	HAULPLY3	LL	.	3.52000-	.	11597.74609-	.73801	INFINITY-	HAULSAW7	LL
					NONE	32838.14844	.73801-	2.78199-	HAULPLY2	LL
145	HAULPLY4	LL	.	3.52000-	.	19408.68750-	.02313	INFINITY-	HAULSAW8	LL
					NONE	35523.41016	.02313-	3.49687-	HAULSAW4	LL

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	LOWER ACTIVITY	...UNIT COST..	..UPPER COST..	LIMITING	AT
					..UPPER LIMIT.	UPPER ACTIVITY	...UNIT COST..	..LOWER COST..	PROCESS.	AT
146	HAULPLY5	LL	.	3.87000-	.	13608.64062-	8.06367	INFINITY-	HAULSAW7	LL
					NONE	5789.53906	8.06367-	4.19367	HAULPLY2	LL
147	HAULPLY6	LL	.	3.87000-	.	21113.97656-	4.90103	INFINITY-	HAULSAW7	LL
					NONE	8982.54297	4.90103-	1.03103	HAULPLY2	LL
148	HAULPLY7	LL	.	3.87000-	.	33137.06250-	.70700	INFINITY-	PLYMILL1	LL
					NONE	34276.97656	.70700-	3.16300-	HAULPLY2	LL
152	DIMMILL	LL	.	15.33000-	.	.	4.90442	INFINITY-	MONEYDIM	LL
					NONE	42249.97656	4.90442-	10.42558-	MONEYSTD	LL
154	TWINMILL	LL	.	36.70000-	.	.	19.46709	INFINITY-	MONEYTWN	LL
					NONE	5406.32422	19.46709-	17.23291-	HAULPLY2	LL
158	PULPMILL	LL	.	53.62000-	.	.	17.11682	INFINITY-	MONEYPLP	LL
					NONE	.	17.11682-	36.50317-	SPNEED	UL
160	SPRUCE	LL	.	35.00000-	.	.	43.39999	INFINITY-	SPNEED	UL
					NONE	INFINITY	43.39999-	8.39999	NONE	
172	AVALCHIP	LL	.	.00010	.	1336.43652-	113.98929	INFINITY-	HAULPLY2	LL
					NONE	3141.36963	113.98929-	113.98939	HAULSAW7	LL
198	PB3/4	LL	.	203.03999	.	INFINITY-	25.38385	INFINITY-	NONE	
					NONE	100358.93750	25.38385-	228.42384	PB3/8	LL
199	PB5/8	LL	.	211.85999	.	INFINITY-	16.86461	INFINITY-	NONE	
					NONE	100358.93750	16.86461-	228.72459	PB3/8	LL
200	PB1/2	LL	.	211.85999	.	INFINITY-	16.86461	INFINITY-	NONE	
					NONE	100358.93750	16.86461-	228.72459	PB3/8	LL
203	WAF5/16	LL	.	296.60986	.	INFINITY-	20.46741	INFINITY-	NONE	
					NONE	141599.93750	20.46741-	317.07727	WAF1/4	LL
204	WAF3/8	LL	.	264.82983	.	INFINITY-	51.16371	INFINITY-	NONE	
					NONE	141599.93750	51.16371-	315.99355	WAF1/4	LL
205	WAF7/16	LL	.	248.17999	.	INFINITY-	67.24596	INFINITY-	NONE	
					NONE	141599.93750	67.24596-	315.42595	WAF1/4	LL
206	WAF5/8TG	LL	.	286.01978	.	INFINITY-	30.69629	INFINITY-	NONE	
					NONE	141599.93750	30.69629-	316.71606	WAF1/4	LL
208	PLY1/2	LL	.	337.45996	.	INFINITY-	212.96162	INFINITY-	NONE	
					NONE	27449.99609	212.96162-	550.42159	PLY1/4	LL
209	PLY3/4	LL	.	284.03979	.	INFINITY-	264.55981	INFINITY-	NONE	
					NONE	27449.99609	264.55981-	548.59961	PLY1/4	LL

SECTION 3 - ROWS AT INTERMEDIATE LEVEL

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	LOWER ACTIVITY	...UNIT COST..	..UPPER COST..	LIMITING	AT
					..UPPER LIMIT.	UPPER ACTIVITY	...UNIT COST..	..LOWER COST..	PROCESS.	AT
3	ALLOWCUT	BS	937063.00000	1330937.00000	NONE	937063.00000	.32919-		TL1AR2	LL
					2268000.00000	998355.44531	.58244-		FTAMT4	UL
4	LIMHAR1	BS	.	1910.00000	NONE	.	INFINITY-		NONE	
					1910.00000	18132.65625	42.78000-		HARVEST1	LL
5	LIMHAR2	BS	.	5853.00000	NONE	.	INFINITY-		NONE	
					5853.00000	14009.85938	55.36600-		HARVEST2	LL
6	LIMHAR3	BS	.	4431.00000	NONE	.	INFINITY-		NONE	
					4431.00000	10237.97656	75.76399-		HARVEST3	LL
7	LIMHAR4	BS	3495.53784	380.46216	NONE	3495.53784	53.03304-		TL1AR2	LL
					3876.00000	11757.09253	93.83080-		TLAMT4	UL
9	TLAMT1	BS	.	.	NONE	140193.93750-	.58283-		HARVEST1	LL
					.	307756.68750	1.98281-		TL1AR1	LL
10	TLAMT2	BS	.	.	NONE	556035.00000-	.58280-		HARVEST2	LL
					.	276392.93750	.31415-		TL1AR2	LL
11	TLAMT3	BS	.	.	NONE	576030.00000-	.58280-		HARVEST3	LL
					.	285663.50000	1.01253-		TL1AR3	LL
14	FTAMT1	BS	.	.	NONE	148935.00000-	.54497-		HARVES1A	LL
					.	374611.56250	2.27892-		FT1AR1	LL
15	FTAMT2	BS	.	.	NONE	594664.68750-	.54494-		HARVES2A	LL
					.	336022.43750	.34620-		FT1AR2	LL
16	FTAMT3	BS	.	.	NONE	616352.00000-	.54467-		HARVES3A	LL
					.	348947.87500	1.04124-		FT1AR3	LL
27	BARK	BS	18013.24609-	18013.24609	NONE	22635.76172-	6.11000-		BRAN-TOP	UL
					.	16886.26978-	21.50446-		HAULPLY3	LL
45	LIMTWIN	BS	.	45312.00000	NONE	.	83.98692-		TWINTRAN	UL
					45312.00000	5406.32422	19.46709-		TWINMILL	LL
51	LIMPULP	BS	.	157500.00000	NONE	.	280.05737-		PULPTRAN	UL
					157500.00000	.	54.42551-		PULPMILL	LL
52	SPNEED	BS	.	.	NONE	INFINITY-	20.30884-		SPRUCE	LL
					.	2909.54346	54.42551-		PULPMILL	LL

SECTION 4 - COLUMNS AT INTERMEDIATE LEVEL

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
97	HARVEST4	BS	1633.71509	75.67000-	.	.	13.32142-	88.99142-	TL1AR5	LL
					NONE	2014.17700	93.83080-	18.16080	TLAMT4	UL
98	HARVEST5	BS	.	84.12999-	.	.	INFINITY-	INFINITY-	NONE	
					NONE	1381.32690	15.75543-	68.37456-	TL1AR5	LL
102	HARVES4A	BS	1861.82251	75.67000-	.	1861.82251	62.48264-	138.15263-	FT1AR2	LL
					NONE	3496.17505	13.31622-	62.35378-	TL1AR5	LL
103	HARVES5A	BS	2088.99976	84.12999-	.	707.67285	15.75543-	99.88542-	TL1AR5	LL
					NONE	2088.99976	INFINITY-	INFINITY	NONE	
116	TL1AR4	BS	46500.26563	87.21999-	.	.	.46803-	87.68801-	TL1AR5	LL
					NONE	56856.27734	5.55389-	81.66610-	LIMS&D	UL
118	FT1AR4	BS	38144.11328	129.59999-	.	38144.11328	3.04979-	132.64978-	FT1AR2	LL
					NONE	71627.94141	.64997-	128.95002-	TL1AR5	LL
122	FT1AR5	BS	47567.59766	129.59999-	.	16114.07812	.69192-	130.29191-	TL1AR5	LL
					NONE	47567.59766	INFINITY-	INFINITY	NONE	
124	HAULSAW1	BS	24226.63672	3.52000-	.	15453.36719	5.32637-	8.84637-	HAULPLY1	LL
					NONE	29622.11719	10.66005-	7.14005	LIMS&D	UL
125	HAULSAW2	BS	52824.11719	3.52000-	.	8509.72656-	5.20912-	8.72912-	HAULSAW6	LL
					NONE	72826.70703	32.94370-	29.42370	LOGS12	UL
126	HAULSAW3	BS	41850.23828	3.52000-	.	3205.62500	.62713-	4.14712-	HAULPLY3	LL
					NONE	51170.64453	6.17099-	2.65099	LIMS&D	UL
127	HAULSAW4	BS	35526.20313	3.52000-	.	19078.73828-	.02313-	3.54313-	HAULPLY4	LL
					NONE	43438.19531	7.26948-	3.74949	LIMS&D	UL
128	HAULSAW5	BS	29317.49609	3.87000-	.	19611.81250	5.92603-	9.79603-	LIMS&D	UL
					NONE	38704.89063	4.97792-	1.10792	HAULPLY1	LL
130	HAULSAW7	BS	14268.86328	3.87000-	.	8300.60156-	4.03089-	7.90089-	LIMS&D	UL
					NONE	54670.03906	.59986-	3.27014-	HAULPLY3	LL
131	HAULSAW8	BS	20053.92187	3.87000-	.	7375.45313	4.53652-	8.40652-	LIMS&D	UL
					NONE	56758.27344	.02239-	3.84761-	HAULPLY4	LL
138	HAULWAF2	BS	39401.75000	3.87000-	.	34078.45312	7.28121-	11.15121-	HAULCHP2	LL
					NONE	42264.72314	20.08965-	16.21965	LIMS&D	UL
139	HAULWAF3	BS	173988.43750	3.87000-	.	156660.64453	3.31930-	7.18930-	LIMS&D	UL
					NONE	182892.08594	2.72192-	1.14808-	HAULPLY3	LL
140	HAULWAF4	BS	104751.43750	3.87000-	.	70423.79688	.70599-	4.57599-	HAULPLY3	LL
					NONE	107200.26392	23.48721-	19.61721	LIMS&D	UL
141	HAULWAF5	BS	24474.14844	3.87000-	.	15138.70703	4.28311-	8.15311-	HAULCHP5	LL
					NONE	49758.67969	.95849-	2.91151-	HAULPLY3	LL
143	HAULPLY2	BS	8509.73047	3.52000-	.	8543.54297-	2.84777-	6.36777-	HAULPLY7	LL
					NONE	26194.48047	3.25230-	.26770-	LIMS&D	UL
149	HAULPLY8	BS	56369.85938	3.87000-	.	19695.42187	.02241-	3.89241-	HAULPLY4	LL
					NONE	60761.00000	8.82687-	4.95687	HAULCHP2	LL
150	STUDMILL	BS	42249.99609	15.33000-	.	.	4.90442-	20.23442-	DIMMILL	LL
					NONE	42249.99609	65.02193-	49.69193	DIMTRAN	UL
151	STUDCAP	BS	42249.99609	5.34000-	.	.	4.90442-	10.24442-	DIMMILL	LL
					NONE	42249.99609	65.02193-	59.68193	DIMTRAN	UL
153	DIMCAP	BS	.	5.34000-	.	.	65.02193-	70.36193-	DIMTRAN	UL
					NONE	42249.97266	4.90442-	.43558-	DIMMILL	LL
155	TWINCAP	BS	.	7.13000-	.	.	83.98692-	91.11692-	TWINTRAN	UL
					NONE	5406.32031	19.46709-	12.33709	TWINMILL	LL
156	BOARDMIL	BS	37999.99609	17.06000-	.	32165.89063	35.06790-	52.12790-	LIMBOARD	UL
					NONE	40714.34448	54.35138-	37.29138	BOARDTRN	UL
157	BOARDCAP	BS	37999.99609	5.95000-	.	32165.89063	35.06790-	41.01790-	LIMBOARD	UL
					NONE	37999.99609	INFINITY-	INFINITY	NONE	
159	PULPCAP	BS	.	99.39999-	.	.	280.05737-	379.45737-	PULPTRAN	UL
					NONE	.	54.42551-	44.97449-	PULPMILL	LL
161	PARTMILL	BS	127197.68750	52.32999-	.	123261.88403	53.56200-	105.89198-	LIMPB	UL
					NONE	136449.01172	103.59531-	51.26532	PBTRAN	UL
162	PARTCAP	BS	100358.93750	10.10000-	.	97253.58716	67.88591-	77.98591-	LIMPB	UL
					NONE	100358.93750	INFINITY-	INFINITY	NONE	
163	WAFERMIL	BS	141599.93750	76.54999-	.	95097.66016	59.07318-	135.62317-	LIMWAFER	UL
					NONE	158409.76172	183.14862-	106.59863	WAFTRAN	UL
164	WAFERCAP	BS	141599.93750	26.54999-	.	95097.66016	59.07318-	85.62317-	LIMWAFER	UL
					NONE	141599.93750	INFINITY-	INFINITY	NONE	
165	PLYMILL1	BS	7952.77344	49.07999-	.	5407.72998	15.22963-	64.30962-	HAULCHP2	LL
					NONE	16203.03516	2.93748-	46.14250-	HAULPLY3	LL
166	PLYMILL2	BS	21539.85156	55.92000-	.	21150.44946	62.23322-	118.15321-	HAULPLY7	LL
					NONE	21555.52883	52.41632-	3.50368-	HAULPLY4	LL

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	LOWER ACTIVITY	...UNIT COST..	..UPPER COST..	LIMITING	AT
					..UPPER LIMIT.	UPPER ACTIVITY	...UNIT COST..	..LOWER COST..	PROCESS.	AT
167	PLYMILL3	BS	17587.39453	60.48999-	.	14742.64380	8.51921-	69.00920-	HAULPLY3	LL
					NONE	18957.43140	28.29126-	32.19873-	HAULCHP2	LL
168	PLYMILL4	BS	7553.55859	62.76999-	.	4173.92896	7.17091-	69.94090-	HAULPLY3	LL
					NONE	8141.97168	65.87219-	3.10220	HAULCHP2	LL
169	PLYCAP	BS	27449.99609	25.53999-	.	4847.26953	272.87085-	298.41084-	LIMPLY	UL
					NONE	27449.99609	INFINITY-	INFINITY	NONE	
170	CHIPLOG	BS	3420.91187	7 94000-	.	.	11.33034-	19.27034-	HAULCHP2	LL
					NONE	10530.18140	6.09030-	.15030	LIMS&D	UL
171	TAX&AD	BS	91449616.0000	.02750-	.	90911348.8750	.10685-	.13435-	LIMS&D	UL
					NONE	INFINITY	.03410-	.00660	AD&TAX	UL
173	SLECTBD	BS	901.26050	305.00000	.	.	229.91345-	75.08655	DIMMILL	LL
					NONE	901.26050	3048.14917-	3353.14917	DIMTRAN	UL
174	CONSTBD	BS	382.35278	200.00000	.	456865.64722-	193.17999-	6.82001	STCONBD	UL
					NONE	382.35278	7184.92188-	7384.92188	DIMTRAN	UL
175	STANDBD	BS	546.21826	195.00000	.	468426.09424-	188.35049-	6.64951	STSTDBD	UL
					NONE	546.21826	5029.44531-	5224.44531	DIMTRAN	UL
176	UTILBD	BS	355.04199	120.00000	.	761724.39551-	115.90799-	4.09201	STUTILBD	UL
					NONE	355.04199	7737.60938-	7857.60938	DIMTRAN	UL
177	ECONOBD	BS	27.31091	85.00000	.	1075849.68909-	82.10150-	2.89850	STECONBD	UL
					NONE	27.31091	100588.87500-	100673.87500	DIMTRAN	UL
178	SLECTBDD	BS	.	305.00000	.	299834.75000-	294.59937-	10.40063	DMSLETBD	UL
					NONE	901.25977	229.91345-	534.91345	DIMMILL	LL
179	CONSTBDD	BS	.	200.00000	.	457248.00000-	193.17999-	[illegible].82001	DMCONBD	UL
					NONE	382.35254	541.93872-	741.93872	DIMMILL	LL
180	STANDBDD	BS	.	195.00000	.	468972.31250-	188.35049-	6.64951	DMSTDBD	UL
					NONE	546.21802	379.35718-	574.35718	DIMMILL	LL
181	UTILBDD	BS	.	120.00000	.	762079.43750-	115.90799-	4.09201	DMUTILBD	UL
					NONE	355.04175	583.62622-	703.62622	DIMMILL	LL
182	ECONOBDD	BS	.	85.00000	.	1075877.00000-	82.10150-	2.89850	DMECONBD	UL
					NONE	27.31090	7587.14063-	7672.14063	DIMMILL	LL
183	CONSTDIM	BS	.	152.00000	.	601642.12500-	146.81679-	5.18321	DMCONST	UL
					NONE	12153.35156	17.04976-	169.04976	DIMMILL	LL
184	STANDIM	BS	.	152.00000	.	601642.12500-	146.81679-	5.18321	DMSTAND	UL
					NONE	3960.08154	52.32512-	204.32512	DIMMILL	LL
185	UTILDIM	BS	.	103.00000	.	887859.62500-	99.48769-	3.51231	DMUTIL	UL
					NONE	5626.04688	36.83080-	139.83080	DIMMILL	LL
186	ECONODIM	BS	.	85.00000	.	1075877.00000-	82.10150-	2.89850	DMECON	UL
					NONE	3359.24146	61.68408-	146.68408	DIMMILL	LL
187	STUD	BS	21766.80469	149.00000	.	.	[illegible].51963-	139.48037	DIMMILL	LL
					NONE	21766.80469	126.20844-	275.20844	DIMTRAN	UL
188	ECONOSTD	BS	3359.24365	85.00000	.	.	61.68408-	23.31592	DIMMILL	LL
					NONE	3359.24365	817.79614-	902.79614	DIMTRAN	UL
189	BD#1BTR	BS	3270.22363	425.00000	.	2768.14917	407.48901-	17.51099	LIMBOARD	UL
					NONE	3270.22363	INFINITY-	INFINITY	NONE	
190	BD#2A	BS	4087.77954	280.00000	.	322517.90796-	270.45190-	9.54810	BOARD2A	UL
					NONE	4087.77954	INFINITY-	INFINITY	NONE	
191	BD#2B	BS	4087.77954	200.00000	.	453159.97046-	193.17999-	6.82001	BOARD2B	UL
					NONE	4087.77954	INFINITY-	INFINITY	NONE	
192	BD#3	BS	4905.33203	150.00000	.	604758.48047-	144.88501-	5.11499	BOARD3	UL
					NONE	4905.33203	INFINITY-	INFINITY	NONE	
193	BD#1BTRT	BS	.	425.00000	.	215175.50000-	410.50732-	14.49268	TWINBD1	UL
					NONE	395.47119	266.12646-	691.12646	TWINMILL	LL
194	BD#2AT	BS	.	280.00000	.	326605.68750-	270.45190-	9.54810	TWINBD2A	UL
					NONE	558.31201	188.50638-	468.50638	TWINMILL	LL
195	BD#2BT	BS	.	200.00000	.	457247.75000-	193.17999-	6.82001	TWINBD2B	UL
					NONE	581.57495	180.96613-	380.96613	TWINMILL	LL
196	BD#3T	BS	.	150.00000	.	609663.81250-	144.88501-	5.11499	TWINBD3	UL
					NONE	790.94238	133.06326-	283.06326	TWINMILL	LL
197	PULP	BS	.	510.00000	.	.	280.05737-	229.94263	PULPTRAN	UL
					NONE	.	54.42551-	564.42551	PULPMILL	LL
201	PB3/8	BS	100358.93750	229.31999	.	5137304.06250-	16.86461-	212.45538	PB5/8	LL
					NONE	100358.93750	INFINITY-	INFINITY	NONE	
202	WAF1/4	BS	141599.93750	317.79980	.	4174095.06250-	20.46741-	297.33240	WAF5/16	LL
					NONE	141599.93750	INFINITY-	INFINITY	NONE	
207	PLY1/4	[illegible]	27449.99609	557.93994	.	387325.00391-	212.96162-	344.97832	PLY1/2	LL
					NONE	27449.99609	INFINITY-	INFINITY	NONE	
210	TRIMROND	BS	13759.58203	8.14000	.	INFINITY-	8.14000-	.	PLYTRIM	UL
					NONE	19801.62500	411.85938-	419.99937	PLYCON	UL

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT. ..UPPER LIMIT.	LOWER ACTIVITY UPPER ACTIVITY	...UNIT COST.. ...UNIT COST..	..UPPER COST.. ..LOWER COST..	LIMITING PROCESS.	AT AT
211	HOGFUEL	BS	4622.51562	6.11000	.	INFINITY-	6.11000-	.	BRAN-TOP	UL
					NONE	5850.50220	19.73557-	25.84556	HAULPLY3	LL
212	MONEYSTD	BS	1909698.00000	.12000-	.	.	.10850-	.22850-	DIMMILL	LL
					NONE	INFINITY	.12000-	.	CAPSTUD	UL
213	MONEYDIM	■S	.	.12000-	.	.	1.43854-	1.55854-	DIMTRAN	UL
					NONE	1909698.00000	.10850-	.01149-	DIMMILL	LL
214	MONEYTWN	■S	.	.12000-	.	.	1.41798-	1.53798-	TWINTRAN	UL
					NONE	INFINITY	.12000-	.	CAPTWIN	UL
215	MONEYBOR	BS	2250739.00000	.12000-	.	1905184.75000	.59206-	.71206-	LIMBOARD	UL
					NONE	INFINITY	.12000-	.	CAPBOARD	UL
216	MONEYPLP	■S	.	.12000-	.	.	.37636-	.49636-	PULPTRAN	UL
					NONE	.	.07314-	.04686-	PULPMILL	LL
217	MONEYPRT	■S	8188290.00000	.12000-	.	7934924.50000	.83204-	.95204-	LIMPB	UL
					NONE	INFINITY	.12000-	.	CAPPART	UL
218	MONEYWAF	■S	37546640.0000	.12000-	.	25216100.0000	.22278-	.34278-	LIMWAFER	UL
					NONE	INFINITY	.12000-	.	CAPWAFER	UL
219	MONEYPLY	BS	5689835.00000	.12000-	.	1004742.00000	1.31644-	1.43644-	LIMPLY	UL
					NONE	INFINITY	.12000-	.	CAPPLY	UL
220	OPERAT$$	BS	48360592.0000	.24000-	.	47987651.3125	.15422-	.39422-	LIMS&D	UL
					NONE	48360592.0000	.14329-	.09671-	PULPMILL	LL